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DEPARTMENT OF COMMERCE

CIRCULAR

OF THE

BUREAU OF STANDARDS

S. W. STRATTON, DIRECTOR

No. 44

POLARIMETRY

[1st Edition]

Issued January 15, 1914



WASHINGTON
GOVERNMENT PRINTING OFFICE

1914

CIRCULARS

No.

1. Verification of Standards and Measuring Instruments.
2. Measurements of Length and Area, Including Thermal Expansion.
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4. Verification of Standards of Capacity.
5. Testing of Clinical Thermometers.
6. Fees for Electric, Magnetic, and Photometric Testing.
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47. Units of Weight and Measure—Definitions and Tables of Equivalents.

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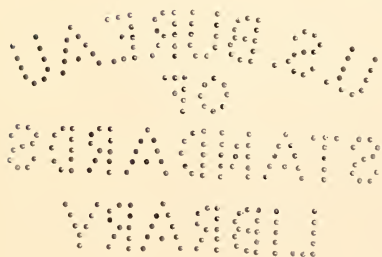


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This circular supersedes Bureau of Standards Circular No. 12, issued July 16, 1906. New material has been added with the object of presenting in condensed form the basic principles of modern polarimetry. In recent years there has been a rapid growth in the applications of polarimetry to the arts and the sciences, with a proportionate increase in the requests made upon the Bureau for information. The preceding circular has therefore been enlarged by a résumé of the work done at the Bureau of Standards and elsewhere, with the object of answering as far as possible inquiries on this subject.

While it is impossible to anticipate all questions that may arise in this field, it is hoped that the present circular will furnish information of a broader character and in greater detail than could be given by letter.



POLARIMETRY

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I. INTRODUCTION

Since the organization of the Bureau of Standards there has been submitted for test a great variety of polariscopic apparatus typifying the designs and methods of construction adopted by American and European manufacturers. The Bureau is equipped with examples of the standard apparatus of the leading polariscope builders, as well as special apparatus for work requiring the highest attainable precision. In the case of most of the apparatus sent to the Bureau for test no intimation is given as to the degree of accuracy desired. In all such cases it is the practice to give such precision as the Bureau's previous experience with the type has shown it to merit. On the other hand, a precision is frequently requested which is greater than the apparatus justifies. In general, two grades of accuracy have been found adequate for polariscopic apparatus, one for the highest commercial accuracy and the other for all scientific work except special research in which the precision of the remaining data entering into the result justifies a still higher accuracy. In such cases the Bureau will be glad to cooperate with investigators, not only in providing for tests of the highest

precision, but also, on request, in furnishing any information at its disposal in reference to methods of measurement and the design and construction of special apparatus. It is also the desire of the Bureau to cooperate with manufacturers, scientists, and others in bringing about more satisfactory conditions relative to the weights, measures, measuring instruments, and physical constants used in polariscopic work, and to place at the disposal of those interested such information relative to these subjects as may be in its possession. Persons interested are invited to visit the laboratories of the Bureau, where leading types of polariscopes may be seen in operation.

II. ABSOLUTE MEASUREMENTS IN CIRCULAR DEGREES

1. POLARIZING SYSTEMS

(a) GENERAL

Biot produced the first instrument for measuring the rotation of plane polarized light by the so-called optically active substances in 1840. It consisted merely of a stand on which were mounted two Nicol prisms and a graduated circle, the analyzing nicol rotating with the circle. Subsequently the simple apparatus of Biot was improved by Mitscherlich and Robiquet, the latter adding the biquartz, which made the setting depend on the transition tint (*teinte de passage*). Some of these instruments are still in use.

In 1860 Jellett invented the first half-shadow polariscope. The utilization of the half shadow was the first important step in the perfection of the modern instrument. Prior to this both the polarizing and analyzing nicols were simple prisms. Jellett's idea was to introduce into polariscope design the photometric principle of making the setting of the instrument depend on the matching of two unequally illuminated portions of the field, the eye under favorable conditions easily detecting very minute differences in intensity. In order to take advantage of this principle he removed a small wedge-shaped section from one-half of a Nicol prism and then cemented the three pieces just as in making an ordinary nicol. In mounting, the divided half was placed toward the analyzer, and each part of this half gave light vibrating in a plane, which made an angle equal to the removed section, with the plane of vibration of the light coming from the other part. This angle is known as the half-shadow angle. The field of the instrument thus appears divided into two parts, and the setting is made by turning the analyzing nicol until they become of equal intensity. The sensibility of the instrument depends on the magnitude of the angle of the half shadow. As the angle diminishes, the accuracy with which a setting can be made increases. However, the total illumination of the

field diminishes with the half-shadow, so that with an angle of about 2.5° the minimum working value is reached.

The advantage of the half-shadow principle was universally recognized, and a number of half-shadow polarizing systems were introduced by various investigators. Two of these—namely, those of Laurent and Lippich—in addition to Jellett's, have been extensively used by polariscope builders.

When plane polarized light of more than one wave length traverses an optically active substance, it emerges with the vibration planes of the individual waves all inclined to each other in a sort of fan-shaped arrangement; the violet waves having been rotated through the greater angle being the most inclined to the original direction of vibration. An analyzing nicol on being rotated will cut out each wave in turn, but it is impossible to darken the field, owing to the fact that some light from each of the remaining waves passes through the analyzer. If the polarizing nicol be of the Jellett type, it will be found impossible to darken either half of the field, and color will always be present. Thus in all polariscopes in which the setting is made by rotating the analyzing nicol it is necessary that the light source be monochromatic, or at least consist of only a few waves of nearly the same length.

(b) LAURENT AND JELLETT POLARIZERS

Of the three half-shadow polarizing systems mentioned above the Laurent alone is limited to the use of a single monochromatic source. In this system a thin plate of quartz cut parallel to the optic axis covers one-half the field of the polarizing nicol. In order that the two rays of the doubly refracting quartz may combine to give plane polarized light in the analyzer, they must have an optical difference of path equal to one-half a wave length. Thus the thickness of the quartz must always be such as to bring this condition about, and its use is then limited to a light source giving the particular wave length for which the condition is fulfilled. The angular position of the new plane of polarization is slightly different from that of the polarizing nicol and the conditions for a half shadow are established. The advantage of this system is due to its adjustable sensibility; the half shadow, being twice the angle between the optic axis of the plate and the plane perpendicular to the principal section of the polarizer, can be readily varied by rotating the polarizer. Inasmuch as the Laurent polarizer requires a monochromatic source it is never combined with a quartz compensating system. The Jellett polarizing nicol, described above, has a fixed half shadow, and therefore the sensibility can not be varied. Its advantage lies in the fact that it does not easily get out of adjustment.

(c) LIPPICH SYSTEM

In the Lippich polarizing system the half-shadow angle is formed by two beams of plane polarized light, which come from two separate nicols, one of which covers but one-half the aperture of the other. If these two nicols are turned until the vibration planes of the light which they transmit coincide, they act as a single nicol. If one of them be rotated through any angle, a half shadow is formed equal to that angle. Because of the ease with which the half shadow can be varied, as well as the high degree of perfection attained by the opticians, we have in the Lippich a most adaptable and sensitive polarizing system. The accuracy with which a setting can be made depends upon how nearly the dark dividing line between the halves of the field vanishes, and with a broad source of light this condition is very nearly attained in the Lippich. However, it requires the use of a monochromatic source if the half shadow is to remain adjustable.

(d) SENSITIVE STRIP SYSTEM

In 1903 Brace¹ described the sensitive strip spectropolariscope. In the ordinary Nicol prisms the extraordinary ray is utilized. It occurred to Brace that it was possible to reverse this condition and use the ordinary ray. Thus instead of a film of liquid between two large pieces of Iceland spar he proposed using a thin piece of spar immersed in liquid and placed in a cell with glass ends, the spar plate covering the entire field and being inclined at an angle of 70° to the axis of the system. To obtain a polarizing system similar to the Lippich it would be necessary to place a second cell with a narrow strip covering one-half the field in the position ordinarily occupied by the small nicol of a Lippich system. If such a system could be perfected, it would have many advantages over the Lippich. Among these may be mentioned the saving of Iceland spar and rectilinear passage of the light through the system. In addition great sensibility would be secured owing to the fact that a practically vanishing line would be obtained between the halves of the field, as the small strip of spar need not be over one-tenth of a millimeter thick. The device was perfected and used by Bates, who subsequently succeeded in combining the two cells into one. The Brace sensitive strip spectropolarizing system is the most sensitive yet devised. It is, however, rather fragile and its use is not recommended except in work requiring the highest obtainable precision.

¹ Brace: *Phil. Mag.*, Jan. 1903, pp. 161-170.

(e) EQUIPMENT

Polariscopes with circular scales for measuring absolute rotations are now made by most polariscope builders. The Bureau is fortunate in having a large Schmidt and Haensch precision instrument with a silver scale reading to $0^{\circ}.001$. The Lippich polarizing system is unusually good, the larger nicol having an available opening of 15 mm. The instrument is mounted on a cast-iron base 1 m in length. Owing to the necessity of controlling the temperature while measuring rotations a large air thermostat, constant to within $0^{\circ}.03$ C, is mounted between the polarizing and analyzing systems. The variations are noted on a mercury thermometer located in the center of the bath. The case is a wooden box 40 cm by 55 cm by 60 cm covered with asbestos. A small hole in each end of the box permits the passage of the light. Access is had to the interior by means of a small door in the side. The temperature, if necessary, is brought to a few tenths of a degree below the desired temperature by means of a copper coil through which ice water flows. Approximate regulation of the ice water is secured through a long arm stopcock. An electric heater then brings the temperature up to and maintains it at the proper degree. The heater is made of small resistance wire wound around a framework which fits inside the box. The current is controlled by means of a relay operated by a mercury contact which in turn is operated by toluene contained in a series of glass tubes so constructed and placed as to give a maximum change of volume in a minimum of time when a small temperature change takes place. The air is kept constantly stirred by a small fan.

An additional precision polarimeter is now in course of construction. It has been designed with the object of obtaining the highest possible accuracy in rotation measurement. It combines for the first time a quartz compensation of unusual perfection, with a circular scale, the wedges being so mounted that they can be instantly swung into and out of the path of the light. The Bureau also possesses facilities for the examination of polarizing systems and separate nicols.

A large Weiss electromagnet equipped with a suitable polariscope is available for the study of magnetic rotation. This magnet is cooled by water circulation, thereby permitting continuous use even when heavy currents are employed.

2. POLARISCOPES WITH CIRCULAR SCALES

(See Fee Schedule 41)

Polariscopes with circular scales will be accepted for test. A thorough examination is given all optical parts. The scale will be checked for as many points as desired.

3. LIGHT SOURCES**(a) GENERAL**

In accordance with the rapidly increasing use of polarimetry in commercial and scientific work there has arisen a demand for greater accuracy. This has resulted in an investigation of the light sources used in order to lessen the largest source of error in precision measurements of this character. The production and utilization of suitable light sources is by far the most difficult problem with which the polariscopist must cope, and it is therefore receiving much careful study at this Bureau. For many years any sodium source was considered suitable for this work. Then came the so-called light filters of Lippich² and Landolt.³ These filters, however, are open to two severe criticisms: The efficiency of the purification is a function of the intensity of the source, and the available light is reduced by absorption in the liquids used in the cells.

Subsequently spectrum filtration came into use for precision work. In this method light from an intense source is passed through an optical system containing a dispersing medium and only the desired wave lengths are permitted to enter the polariscope.

(b) SODIUM

Until recently the sodium lines have been the one intense source with which a large percentage of the precision work has been done. This source has been used for determining practically all the polarimetric constants as well as for the standardization of quartz control plates. Unfortunately the two sodium lines are difficult to separate from the remainder of the spectrum and as the flame is intense, there is danger of the lines reversing. In 1906 a careful study of spectrum lines as light sources for polarimetric work was made at this Bureau. It was found that the lack of intensity, the high dispersion necessary for purification, the presence of other lines of considerable intensity in the neighborhood of D_1 and D_2 , as well as the unstable line structure under certain conditions, renders this source far from satisfactory. Owing to the great precision required in present-day polariscopic measure-

² Lippich: *Zs. für Instrk.*, 12, p. 340; 1892.³ Landolt: *Ber. d. chem. Ges.*, 27, p. 2872; 1894.

ments, intensity is of paramount importance. Even in commercial instruments the half-shadow angle is generally not over 10 degrees, which means that the polarization plane of the analyzing nicol is practically at right angles to the planes of the polarizing system. Thus only a very small fraction of the incident light ever reaches the eye of the observer. After an extensive investigation the Bureau has found that for an intense sodium source the best results are obtained by feeding some form of fused Na_2CO_3 into an oxyhydrogen flame. In utilizing this source a rod of this substance is placed in the flame at one of the positions shown in Fig. 1. The line structure of the sodium lines obtained by this method was studied with an echelon spectroscope. The lines were found to be extremely sharp and to differ from the arc spectra by the absence of the characteristic haziness of the edges. If displacements as large as $0.5 \text{ m}\mu$ had occurred, they would have been readily detected. The broadening was at all times symmetrical. In this respect the observations agree with the more recent work of other observers, but are contradictory to the results obtained by Ebert⁴ which have been accepted in polariscopic work.

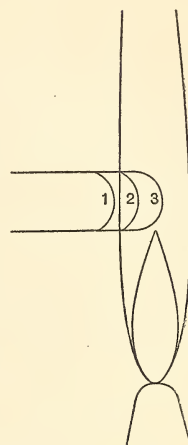


Fig. 1.—Sodium light source

By careful manipulation of the flame in position three reversals of the lines took place. D_2 preceded D_1 in this respect.

TABLE 1

Structure of Sodium Lines at Different Intensities

Spectrum line.	Relative intensity	Position 1, width $\text{m}\mu$	Position 2, width $\text{m}\mu$	Position 3, width $\text{m}\mu$		
				Na_2CO_3 melting slowly	Na_2CO_3 melting very rapidly	
D_1	1.0	0.008	0.02	0.3-0.4	0.4	Reversed 0.6
D_2	1.6	0.008	0.02	0.3-0.4	Reversed 0.6	Reversed 0.6

It is thus evident that so far as their line structure is concerned the sodium lines can be depended upon to give a sufficiently definite optical

⁴ Ebert: Wied. Ann., 34, p. 39; 1888.

center of gravity up to the point of reversal in position 3 (Fig. 1). However, very noticeable variations in polariscopic measurements are likely to be observed with sodium sources at different intensities. These variations, it is believed, are not due to changes in the line structure of the source, but to the difficulty of excluding all extraneous light even with a very narrow slit and a dispersion sufficient to separate D_1 and D_2 . This extraneous light constitutes a different percentage of the total illumination whenever the intensity of the source varies. It may, therefore, appreciably affect the optical center of gravity when the field appears dim, and inversely when bright. Aside from the color and stability of the sodium lines up to reversal there is nothing in their favor as a polariscopic source. The flame requires the constant attention of an assistant, and even in reversal the intensity is not nearly sufficient to permit of the use of the greatest sensibility of a good polarizing system.

(c) MERCURY

It is proposed to use the green line of incandescent mercury vapor, $\lambda = 546.1\text{m}\mu$,⁵ as the standard source for all accurate polariscopic work. Quartz mercury-vapor lamps as now made are reliable in action. If sufficient care is exercised in preparing the mercury and exhausting the lamps, the five characteristic lines only will be obtained in the visible spectrum and with great intensity.

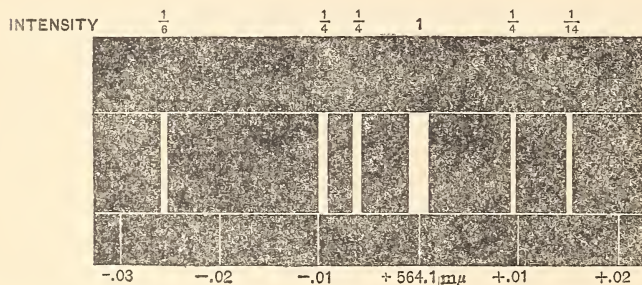


Fig. 2.—“Yellow green” line of mercury vapor

Different observers have found markedly different line structures

for the line $\lambda = 546.1\text{m}\mu$, depending upon the method of analysis employed. The map in Fig. 2 was obtained with the echelon with 1.8 amperes passing through the lamp. The fractional values given are the relative intensities as nearly as they could be estimated. It was found impossible to decide whether the satellite -0.024 belongs to the positive or negative side of the primary. When the current was increased to more than 2.1 amperes, the

⁵For greater clearness and to conform to the system of numeral prefixes in use with metric and cgs units, the numeral prefix *micro-* ($=10^{-6}$) is abbreviated μ in combination, and *milli-* ($=10^{-3}$) is abbreviated *m*, so that *micro-micron* (10^{-12} meters) would be abbreviated $\mu\mu$ and *milli-micron* (10^{-9} meter) abbreviated $m\mu$, as in this circular.

satellite -0.055 increased in intensity until it about equaled the primary. The difference in wave lengths of the extreme satellites is less than $0.04\text{m}\mu$. With a different source Fabry and Perot⁶ found $0.035\text{m}\mu$ and Houston⁷ $0.0215\text{m}\mu$. The distance between D_1 and D_2 is fifteen times $0.04\text{m}\mu$. As far as it has been possible to determine, the line structure for the quartz lamp under widely varying conditions is such that for polariscopic purposes $\lambda = 546\text{m}\mu$ is a monochromatic source of great intensity and perfect reliability. In measuring a rotation of 250° no differences could be detected due to changes in the emission, and probably none for much larger rotations. The quartz lamp requires little attention and can be operated indefinitely. Since only the lines $\lambda = 579, 576, 546, 435$, and $404\text{ m}\mu$ are present the difference in wave length is such as to permit of perfect separation of the line $546\text{m}\mu$ by even a relatively small dispersion, and without bringing other lines in close proximity to the edges of the slit. Hence, this source permits the elimination of practically all diffused light.

Since its adoption as the official source for polarimetric measurements by the Bureau of Standards its universal acceptance has been recommended by a number of investigators. The Bureau urges its general use especially when measuring circular degrees in research and precision work, to the end that reliable comparisons may be made between the results of different investigators.

(d) CADMIUM AND LITHIUM

The necessity for a number of suitable line sources for polariscopic work has resulted in numerous investigators giving much time to the subject. So far as possible it is desirable that the lines utilized be uniformly distributed throughout the visible spectrum.

Lowry⁸ has suggested the following: Lithium, 670.8 , red; cadmium, 643.8 , red; sodium, 589.3 , yellow; mercury, 546.1 , green; cadmium, 508.6 , green; cadmium, 480.0 , blue; mercury, 435.9 , violet. 670.8 and 589.3 are obtained from flame spectra, and 546.1 and 435.9 from the quartz mercury lamp. The cadmium lines 643.8 , 508.6 , and 480.0 Lowry suggests be obtained from a rotating arc. The electrodes must rotate in opposite directions at a speed sufficiently high to prevent flickering. As electrodes he uses an alloy of 28 per cent cadmium and 72 per cent silver. The melting point is 860° . This method has been used at the Bureau and is capable of giving excellent results. The rotating arc is, however, rather difficult to manipulate.

⁶ C. R., p. 409; 1898.

⁷ Houston: Phil. Mag., 7, p. 456; 1904.

⁸ Phil. Mag., 18, pp. 320-327; 1909.

4. QUARTZ CONTROL PLATES

(See Fee Schedule 44)

(a) METHOD OF TESTING

Inasmuch as precision work of the highest type is frequently called for in meeting the demands for accuracy in standardizing quartz control plates, the mercury line $\lambda = 546.1\text{m}\mu$, for the reasons outlined above is used entirely. In order to utilize this same source the temperature coefficient, α , of quartz for $\lambda = 546.1\text{m}\mu$ as well as the constant $\frac{\phi_{\lambda=546.1}}{\phi_{\lambda=589.2}}$ (where ϕ is a rotation) were determined. It was thought advisable to measure α , although V. Lang,⁹ Sohncke,¹⁰ and Le Chatelier¹¹ state that it has the same value for all wave lengths. We have

$$\phi_t = \phi_o (1 + \alpha t) \quad (1)$$

where ϕ_t is the rotation at temperature t and ϕ_o at zero. For any other temperature t we have

$$\phi_{t_1} = \phi_o (1 + \alpha t_1) \quad (2)$$

Hence

$$\alpha = \frac{\phi_{t_1} - \phi_t}{\phi_t t_1 - \phi_{t_1} t} \quad (3)$$

The measurements were made with the most improved types of apparatus. $\lambda = 546.1\text{m}\mu$ was separated by means of two dense prisms. The left rotating quartz plate was placed in a water cell closed with glass end plates. The cell could be opened and the quartz removed without disturbing the mounting of these plates. This is of the greatest importance, as it insures constancy of the optical path at all times save that caused by the presence and absence of the quartz plate. Water at the desired temperature flowed through the glass cell during all measurements. Twenty consecutive settings were always made—5 on the zero point, 10 with the quartz inserted, and 5 on the zero. By computing α from the value of ϕ at temperatures between 4°C and 50°C the following was obtained:

$$\alpha = 0.000144.$$

Hence

$$\phi_t = \phi_o (1 + 0.000144t) \quad (4)$$

between 4°C and 50°C .

In measuring $\frac{\phi_{\lambda=546.1}}{\phi_{\lambda=589.25}}$ a large number of determinations were made, practically all of which were concordant. However, in order to eliminate the personal equation and avoid as far as possible errors due to the character of the sodium source, the value of ϕ is computed from the measurements

⁹ V. Lang: Pogg. Annalen 156; 422 p. 1875 ¹⁰ Sohncke: Wied. Annalen 3, 516. ¹¹ Le Chatelier: C. R. 109-244 (1889).

of five plates, whose sodium value has recently been determined at the Physikalisch-Technische Reichsanstalt. The mean of this value and that of the Bureau was taken as the rotation for $\lambda = 589.25$. The rotations were measured in part with a sensitive strip polarizing system. The greater number, however, were made with an exceptionally good Lippich system.

The average value obtained was

$$\frac{\phi_{\lambda=589.25}}{\phi_{\lambda=546.1}} = 0.85074 \quad (5)$$

Thus any quartz rotation for the wave length 589.25 may be obtained by measuring the rotation for the wave length 546.1 and multiplying it by the constant 0.85074. By this method the errors due to the character of the sodium source of light are eliminated and the measurements of one observer may be readily compared with those of another. Certificates show the rotation in circular degrees at 20° C for wave lengths $\lambda = 546.1\text{m}\mu$ and $\lambda = 589.25\text{m}\mu$. The latter is the so-called optical center of gravity of the two sodium lines D_1 and D_2 .

(b) SPECIAL TESTS

Additional data upon quartz control plates submitted for test may be had by special arrangement. Standardization for wave lengths other than $\lambda = 546.1\text{m}\mu$ and $\lambda = 589.25\text{m}\mu$ will be made provided the order of accuracy desired is consistent with the intensity of the source available.

A test for the so-called "axis error" will also be made. Often, for special purposes, it is desired to know the order of accuracy with which the normal to the plate coincides with the optic axis. In well-cut plates this angle is often less than one minute of arc. The possibility of errors in rotation from this source is relatively small.

(c) SPECIFICATIONS

Control plates should be optically homogeneous with the faces plane, parallel, and cut accurately at right angles to the optic axis. They should invariably be mounted loosely in a metal frame the axis of which forms an angle of 90° with faces of the plate. The amount of play in every direction between the plate and the surrounding frame should be as small as possible, but the metal should exert no pressure upon the plate. The Bureau does not issue certificates for plates mounted in wax, but plates so mounted will be tested and a statement of the rotation issued. The Bureau reserves the right to reject any plate showing faults which tend to make it unreliable. The sugar value of control plates is discussed below under saccharimeters.

III. SACCHARIMETERS

(See Fee Schedule 43)

1. DEVELOPMENT

In the development of the saccharimeter there are two factors that have of necessity received most consideration. They are, first, sufficient illumination of the field for average work and, second, the highest sensibility obtainable without too great a sacrifice of other desirable features. The application of the photometric principle as realized in the half shadow nominally requires the use of a nearly monochromatic light source such as is used on polariscopes for absolute measurements. Unfortunately a monochromatic source of sufficient intensity and otherwise suitable for all polarimetric work has never been realized. In order to obviate this difficulty, Soleil, a Parisian optician, as early as 1848 invented the first quartz wedge compensation and applied it to the polariscope of Robiquet. He used negatively rotating quartz, the vibration planes of the different waves being thus returned to the original vibration plane common to all. Since the calibrated wedge is driven across the field until conditions are as they were before the rotating substance was placed in the instrument, rotary dispersion is practically eliminated and white light may be used.

The absence of light sources of sufficient intensity has always been one of the most potent factors in influencing the design of saccharimeters. The higher limit of the sensibility has been almost entirely determined by this factor. Even with the average half shadow of six to eight degrees the polarizing and analyzing nicols are practically crossed, so that only a mere fraction of the incident light ever reaches the eye of the observer; and if the half shadow is decreased in order to increase the accuracy with which observations can be made, the intensity of the light transmitted is rapidly reduced. Thus monochromatic sources are inadequate in intensity when even fairly accurate settings are to be made, unless the active substance whose rotation is to be measured is quite transparent. Unfortunately this is not the case with most of the optically active liquids. This is especially true of the average raw sugar solution, and hence Soleil, as stated above, invented the quartz wedge compensation which permits the use of white light with its relatively great intensity.

The necessity for using white light has resulted in the quartz-compensating instrument displacing practically all other saccharimeters, as is evidenced by the similarity in the perfected instruments of Frič, Schmidt and Haensch, Peters, Reichert, and others. This has been brought about

despite the fact that the wedge prevents the use of the adjustable half shadow of the Lippich polarizing system. Thus, while the best results in the designing of polariscopes for use with a white light source have so far been obtained by using the Lippich polarizing system and a quartz wedge compensation, all makes have had the great weakness of an unadjustable half shadow, and therefore a fixed sensibility. Only one value of the half shadow can be used, and it must necessarily be large enough to give sufficient light to read, for example, the darkest colored raw-sugar solutions. When polarizing substances having a small coefficient of light absorption, as the better grade of sugars, and the observer has more light than he needs, he still has available only the low sensibility which corresponds to that value of the half shadow which gives sufficient light to polarize substances with a relatively large coefficient of absorption, such as very dark raw sugars. If, then, it were possible to retain the quartz compensation and at the same time have the half shadow adjustable, an advance in polariscope construction would be made comparable with the invention of the wedge.

The defect due to the lack of an adjustable sensibility on a white light instrument has been in evidence not only in ordinary use but especially when the saccharimeter was used for research work. The ordinary quartz compensating polariscope is utilized in practically every chemical laboratory. The highest available precision of the instrument is required to meet the demands of routine use. Yet the investigator has been compelled to depend upon it. The futility of taking a large number of observations on an instrument sensitive to 0.15 per cent and using the average value as good to 0.015 per cent is too well known to need discussion here. Nevertheless, the chemist has been compelled to do this because the majority of the research problems involving the use of the polariscope require the measuring of rotations to less than 0.1 per cent. There can be no question that the present status of polarimetry would have been immeasurably advanced had there been a saccharimeter capable of being read to 0.01 per cent in the hands of chemists for the past 25 years.

In order to build a white light polariscope with an adjustable sensibility the analyzing nicol would have to rotate through a definite angle as the half-shadow was varied. In such an instrument it is not sufficient that the half-shadow be merely adjustable, but the far more difficult requirement must be met of having it adjustable without shift of the zero point. This is indispensable for two reasons; first, to permit of making polarizations with the same rapidity as on an ordinary saccharimeter, and, second, to eliminate the danger of the observer not properly setting the analyzing nicol whenever the

half-shadow is changed. The designing of an instrument to meet these requirements would be comparatively simple if the vibration plane of the analyzing nicol bisected the half-shadow when the halves of the field were matched. In general, the intensities of the light emerging from the large and small nicols of a Lippich system are unequal. Hence when the analyzer is set for a match its position is different from what it would have been had the beams been of equal intensity. The angular difference, δ , between the two positions of the analyzer was found by Bates¹² to be

$$\delta = \tan^{-1} \left(\tan^3 \frac{\alpha}{2} \right) + 0.0103\alpha \quad (6)$$

It is thus evident that if the vibration plane of the analyzer always bisects the half-shadow the zero of the instrument will be in error by the angle δ , and the amount of the error depends on the half-shadow α . The zero error δ is much smaller and much more nearly linear with α than had been suspected, so that in order to have a negligible change in the zero point as the half-shadow is varied it should be necessary to make only a slight modification of the ideal gear ratio in which the analyzing nicol always turns through one-half the rotation of the large nicol of the Lippich polarizer.

(a) ADJUSTABLE SENSIBILITY

The instrument shown in Fig. 3 was designed at the Bureau of Standards in 1907 to fulfill the theoretical conditions mentioned above, and is one of a number built for the Bureau and the United States Customs Service. It was constructed by the firm of Messrs. Josef & Jan Frič, Prague, and has been brought to a high degree of perfection. It is double quartz wedge compensating and has a Lippich polarizing system with the highest grade of nicol prisms. The adjustable sensibility is attained by a simple mechanism which acts to maintain the analyzer in the proper position to keep the two halves of the field at equal intensities, no matter how the half-shadow may be varied to suit the pleasure of the observer. In order to accomplish this the vibration plane of the analyzer is constantly maintained at the angle δ to a line bisecting the half-shadow. A constant match of the field results. Messrs. Frič have succeeded in doing this to such a degree of perfection that there is no observable change in the zero point for a half-shadow range of $2^\circ.5$ to 15° . The analyzing nicol and the large nicol of the polarizing system are mounted in bearings and driven by gears from the common horizontal connecting rod shown in the figure. The half-shadow is varied by turning

¹² Bull. B. S., 4, pp. 461-466, and 5, pp. 193-198.

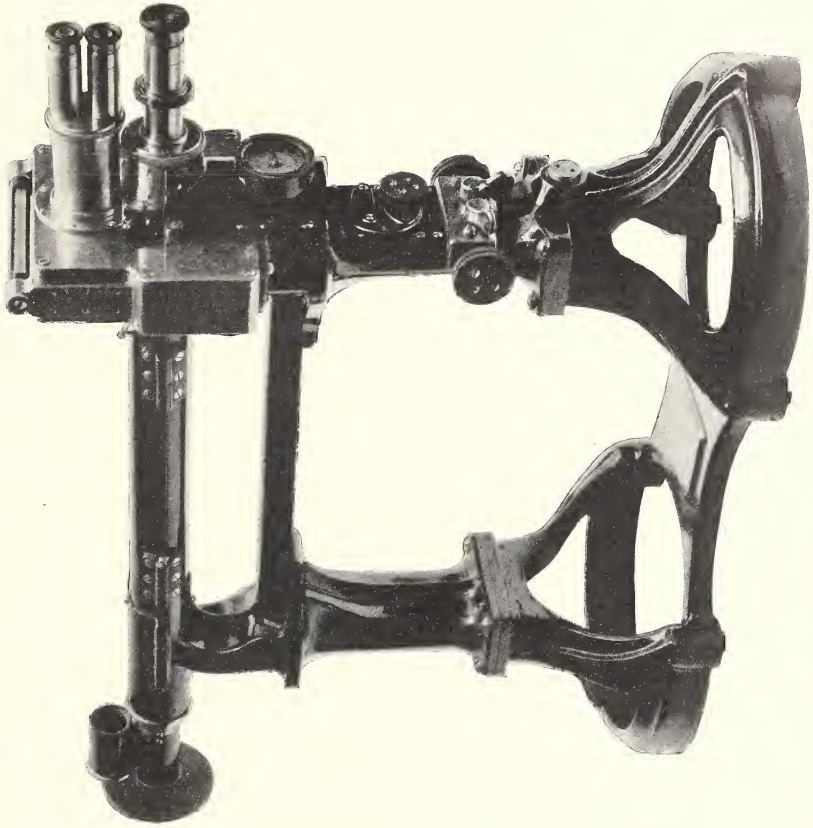


Fig. 3.—Quartz-wedge polariscope with adjustable sensibility

the milled head on the end of this rod. The angle of the half-shadow is indicated on an engraved dial 3 cm in diameter in constant view of the operator.

Another important improvement¹³ has been made in the location of the milled heads which move the quartz wedges. Heretofore polariscope builders have mounted these heads on the ends of vertical rods, thereby forcing the hand and arm of the observer into a cramped and unnatural position while making the setting. It will be observed that the milled heads are at right angles to the customary position, thereby overcoming this objection. The wedges can be instantly clamped rigid at any position of the scale.

Both the right and left rotating wedges are of unusual length, reading from $\pm 5^\circ$ sugar to $\mp 105^\circ$ sugar. Their scales are the regulation type ordinarily used on Frič saccharimeters. The scale now used by manufacturers generally is of metal and read by reflected light. Owing to the shortness of the wedge the reading is necessarily made by means of a magnifying telescope. A heavy black line thus separates the vernier and the scale proper. Owing to the fact that the eye must bridge this line and that the edges of the rulings are not sharp, interpolation of the vernier to hundredths is impossible and in many cases it is very easy to make an error of 0.1° sugar. The Frič scale, which has been in use for some years, is made with the lines etched on ground glass, which permits of very sharp rulings. What is of even greater advantage it is read by transmitted light, the black dividing line between the vernier and the scale being thus eliminated. Not only is this scale much easier on the eye of the observer, but it also permits of reading accurately to 0.01° sugar. It is illuminated by waste light collected by a 45° mirror, located in front of the polarizing system. Thus it is not necessary to have any extraneous light in the room, as all the light used enters the instrument through the collecting lens in the end of the tube. In investigations utilizing the saccharimeter, where temperature corrections are to be made, it is necessary to know accurately the temperature of the quartz wedges. Polariscope builders do not generally make provision for this. A thermometer (10° – 40° C, in one-fifth degrees) with a horizontal scale and with its bulb between the quartz wedges, has accordingly been mounted in a brass case on top of the metal box containing the compensator. For all ordinary sugar testing, where the temperature of the room changes slowly, the reading of the thermometer is practically the

¹³ Bates: Bull. B. S., 4, pp. 461–466, and 5, pp. 193–198; Reprints 86 and 98.

temperature of the room. The observer is thus able to take the temperature with the same facility that he reads the scale on his wedge, since the thermometer scale is in a similar position and is illuminated by the same light source.

When a tube of liquid is placed in a polariscope, there is always present a certain amount of haziness which seems to overlies the field of view. It is due to depolarized light and interferes with the focusing and the accurate matching of the halves of the field. This has been practically eliminated by proper diaphragming. When a tube is placed in the instrument, the observer sees a clear, sharply defined circular field with no extraneous light. The observing, as well as the two reading telescopes for the scale, have screw adjustments which permit of accurate and rapid focusing. Another minor improvement has resulted from making the base of the instrument exceptionally heavy and mounting it on rubber tips. The resulting inertia of the instrument and friction on its supporting bench prevent accidental shifting with reference to the light source.

A two-fold object has been kept constantly in view in designing this instrument. The first has been to produce a saccharimeter of great flexibility for regular commercial testing and to correct the defects of the ordinary instrument. The second has been to provide the chemist with a white-light instrument suitable for research work. The result has been the production of an instrument of a greater range of adaptability than any polariscope heretofore built. In measuring rotations with the greatest possible accuracy, or when it is desired to make the settings with the least possible strain on the eye, the observer has only to change the half-shadow angle until he has just sufficient light to bring the two halves of the field to the same intensity. He then has for his eye an instrument so adjusted as to give the maximum sensibility for making the setting, no matter what the character of the substance whose rotation is being measured.

(b) BASIS OF CALIBRATION

The specifications defining the 100° point of saccharimeters have been changed many times since Ventzke defined the normal sugar solution in 1842. At the present time there are three sugar scales in common use—the French scale, the German or Ventzke scale, and the scale agreed upon by the international committee for unifying methods of sugar analysis (International Sugar Commission).

(1) *French Scale.*—On the French sugar scale the 100° point is fixed by the rotation, for sodium light, of a control plate of right-handed quartz

1 mm in thickness, with its faces perpendicular to the optic axis. The normal sugar solution is then obviously that solution which contains the proper weight of sucrose in 100 cc to give a rotation, in a 200-mm tube, equal to that of the 1-mm quartz plate. Here, as in all polarimetric measurements made at an early date, we find a marked difference in the results of various investigators. The values for the rotation of the quartz plate vary from $20^{\circ}.98$ to $22^{\circ}.67$. In 1895 E. Gumlich,¹⁴ of the Physikalisch-Technischen Reichsanstalt, made a very careful determination of the rotation of the quartz plate with the following result:

Pure sodium light is rotated by a quartz plate 1 mm in thickness at a temperature of 20° , $21^{\circ}.718 \pm 0.0005$. This value has been generally accepted. Subsequent determinations of this important constant by other investigators seem to indicate a slightly higher value, namely, $21^{\circ}.723$. The grams of sucrose necessary to give the same rotation in 100 cc as the 1-mm quartz plate have also varied.¹⁵ Over 20 different values have been assigned to this quantity, the amounts ranging from 16.0 g (Dubrunfaut) to 16.471 g (Clerget and Biot). The old normal weight established for French instruments was 16.35 g, and this weight is still largely used in technical work with the Soleil-Duboscq saccharimeter. In 1875 the value of Girard and de Luynes, 16.19 g, was adopted as the official weight and remained such for more than 20 years. In 1896 the International Congress of Applied Chemistry at Paris established the value of 16.29 g sucrose dissolved at 20° C in 100 metric cc, and this is the official weight used at present by the French Ministry of Finance.

(2) *German or Ventzke Scale.*—Ventzke, in 1842, proposed a method for preparing the normal sugar scale which would make the use of a balance unnecessary. He determined that the normal sugar solution should have a density of 1.100 at $17^{\circ}.5$ C referred to water at $17^{\circ}.5$ C. The 100° point of many saccharimeters was fixed by the use of this solution. However, it was soon found that the standardization effected by this means was unsatisfactory when the instrument was placed in use. Accordingly 26.048 g, the weight of sucrose in 100 cc of Ventzke's solution, was taken as the normal weight and the specific gravity method abandoned. It is thus entirely reasonable to suppose that many of the old instruments were made for use with a weight of 26.048 g in 100 cc. When the Mohr sugar flask came into general use in 1855, polariscope builders began determining the 100° point by the use of this flask and the normal weight 26.048 g.

¹⁴ Zs. für Instrk., 1896, p. 97.

¹⁵ Browne: Handbook of Sugar Analysis, p. 112.

This was an entirely new basis, as 100 Mohr cc = 100.234 cc. Most of the saccharimeters in use to-day have their 100° points determined on this basis, which may be more fully stated as follows:

The 100° point is determined by polarizing, in a 200-mm tube, a solution containing 26.048 g of sucrose, weighed in air with brass weights, in 100 Mohr cc at 17°.5 C, the temperature of the quartz wedges, as well as the polarization temperature, being 17°.5 C. From 1855 to 1900 practically all saccharimeters except those using the French scale had their 100° points determined on the basis given by this last definition of the Ventzke scale.

(3) *International Scale.*—The Ventzke scale, although in general use, has never been fully understood by polariscopists generally. This has led to much confusion and to the use of 100-cc flasks on instruments standardized for use with the Mohr flask. In addition 17°.5 C is well below the temperature of the average laboratory. Because of these and other considerations the International Sugar Commission at the Paris meeting in 1900 recommended the use of a new definition of the 100° point based upon true cc and a standard temperature of 20° C. Owing to the absence of a more suitable term and in order to divorce it as completely as possible from confusion with the Ventzke scale the new scale will be referred to as the International Sugar Scale because of its origin. The change to 20° C necessitated a change in the normal weight in order to keep the new scale comparable with the Ventzke. Correcting for the change in the specific rotation (-0.000184), the expansion of a glass tube ($+0.000008$), quartz wedge (-0.000130), and metal scale (-0.000018), the new weight becomes 26.000+ g. The International Sugar Scale was then defined at the Paris meeting as follows: The graduation of the saccharimeter shall be made at 20° C, 26 g of sucrose dissolved in water and the volume made up to 100 metric cc, all weighings to be made in air with brass weights, the completion of the volume and the polarization being made at 20° C will determine the 100° point.

The advantages of the new scale were at once appreciated. It has been adopted by the United States Bureau of Standards, the United States Treasury Department, the Physikalisch-Technische Reichsanstalt, the Institute für Zucker-Industrie, and also by the makers of saccharimeters. All saccharimeters and quartz control plates sent to this Bureau for test will, unless requested to the contrary, be standardized according to the International Sugar Scale for a white light source filtered through a 15-mm layer of a 6 per cent solution of potassium bichromate.

(4) **Conversion Factors.**—In order that comparisons may be made between the readings of different scales it is necessary to know the conversion factors. A number of these have been collected by Browne¹⁶ into a convenient table.

TABLE 2
Saccharimeter-Scale Conversion Factors

Scale	Equivalent
1° International sugar scale.....	0934657 angular rotation D
1° angular rotation D.....	2988542 International sugar scale
1° French sugar scale.....	0921666 angular rotation D
1° angular rotation D.....	4961553 French sugar scale
1° French sugar scale.....	0962516 International sugar scale
1° International sugar scale.....	1959960 French sugar scale
1° Wild sugar scale.....	0913284 angular rotation D
1° angular rotation D.....	7952814 Wild sugar scale
1° Wild sugar scale.....	0938329 International sugar scale
1° International sugar scale.....	2960903 Wild sugar scale
1° Wild sugar scale.....	0961313 French sugar scale
1° French sugar scale.....	1963098 Wild sugar scale

(Normal weight=26.00 g International scale; 16.29 g French scale; 10.00 g Wild scale.)

The international sugar scale is employed upon the Schmidt and Haensch, Peters, and Frič saccharimeters. The French sugar scale is employed upon the Laurent-Jobin and Duboscq-Pellin saccharimeters.

2. LIGHT SOURCES

It has been most unfortunate in the development of saccharimetry that careful consideration has not been given earlier to the question of suitable light sources and particularly to the influence of the source on the saccharimeter reading. Manufacturers have neglected to specify the character of source for which the scales of their instruments were constructed; and it has been common practice among the users of saccharimeters to employ whatever source happened to be most convenient without consideration of its effect on the reading.

(a) BICHROMATE ABSORPTION CELL

Owing to the fact that the rotation dispersion curves of optically active substances are not identical, the quartz wedge does not completely return the polarization planes of all waves to their original positions after they have been rotated by the substance being tested. In the case of a solution of

¹⁶ Brown's Handbook of Sugar Analysis, p. 145.

sugar the dispersion is nearly the same as that of quartz, but the divergence is sufficient to cause the halves of the field to appear of different tints. The field must appear uniform in color if the readings by different observers are to agree. Obviously the same instrument will also give different readings with different sources inasmuch as the luminosity curves of the sources are different. In testing sugar the field may be made almost uniform in color for all sources of ordinary intensity by placing a cell of potassium bichromate solution between the polarizing system and the lamp. This eliminates by absorption most of the shorter waves from the visible spectrum. Some saccharimeters are provided with a cell, fitted in the metal tube which houses the polarizing system, for containing the absorbing solution. Owing to their small diameter this Bureau has not found these cells satisfactory. Better results have been obtained by using a cell with a diameter of 40 or 50 mm placed in front of the saccharimeter. Any thickness may be used. The optical path in the bichromate solution should, however, always be equivalent to a layer of liquid 15 mm thick for a 6 per cent solution. If the cell is not 15 mm in thickness the concentration of the solution must be changed accordingly. A simple rule is always to have the product of the thickness in millimeters and the per cent concentration equal to 90.

Owing to the fact that the bichromate absorption cell is indispensable when a white light source is used and that a suitable and convenient form has not been available, the type ¹⁷ shown in Fig. 4 has been designed at this Bureau especially for saccharimetric use. The cell is entirely of glass with an inner separation of the plate-glass walls of 15 mm. It is mounted in a metal frame carried on the stand F. The height is adjustable with ample range to fit any saccharimeter. To utilize the filter it is only necessary to fill the cell with a 6 per cent solution of $K_2Cr_2O_7$ and place it between the light source and the polarizer, preferably as close to the latter as possible.

(b) INFLUENCE ON READING

In 1904 Schönrock ¹⁸ made an investigation of the effect of different sources on the saccharimeter reading. His results are summarized in Table 3.

¹⁷ Manufactured by Bausch & Lomb, Rochester, N. Y.

¹⁸ Z. Ver. Deut. Zuckerind., pp. 521-558.

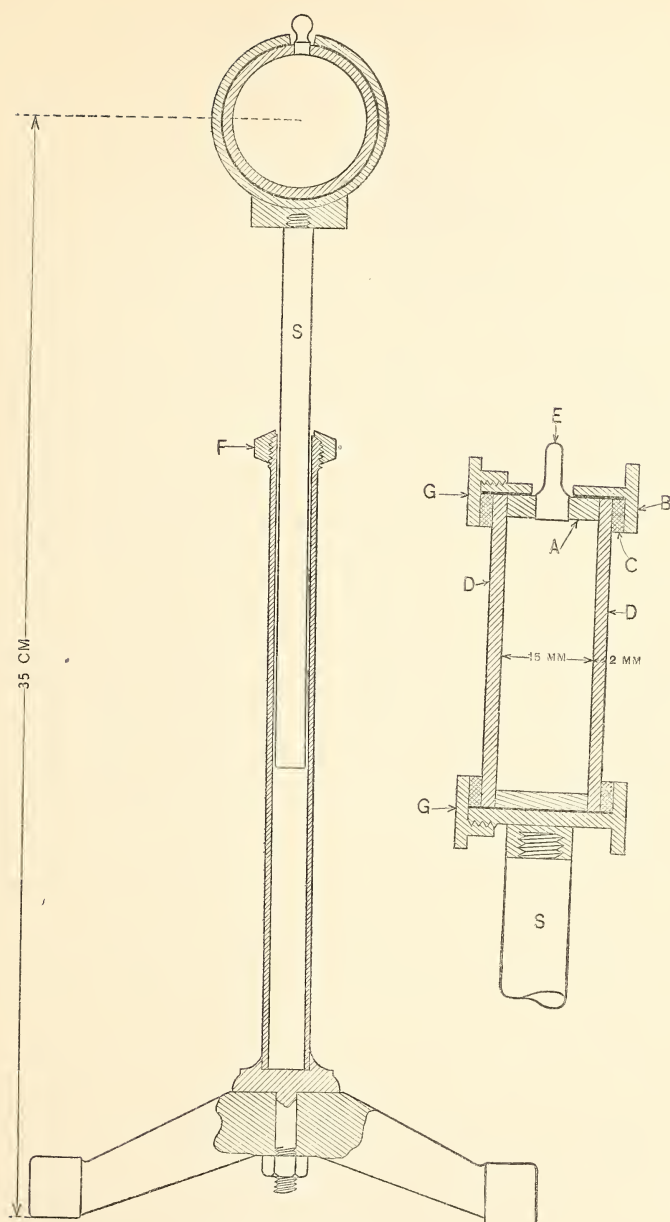


Fig. 4.—Absorption cell

TABLE 3
Effect of Light Sources on the 100° S Point

Light source	Purification	Optical center of gravity in $m\mu$	Saccharimeter reading
White light.....	Bichromate solution.....	About 600	100.00
Sodium.....	Dispersion by prism.....	589.3	100.03
Do.....	Bichromate solution.....	589.3	100.03
White light.....	None.....	About 551	100.12
"Yellow-green" mercury line.....	Dispersion by prism.....	546.1	100.15
Electric.....	Color-glass 436 ^{III}	About 520	100.224

The above data was obtained with uncolored sugar solutions. It will be observed that with a white-light source the presence of the bichromate absorbing solution makes a difference of 0°.12 in the saccharimeter reading. It thus becomes important that the instrument be used under the same conditions as prevailed at the time it was standardized. If, as is usually the case, a quartz control plate is used the plate should be read in the instrument under the same conditions as prevailed when the plate was standardized.

(c) TYPES OF LAMPS

(1) **Monochromatic.**—Many different types of lamps designed for use with the saccharimeter have been brought out. They may be divided into two classes: Those giving a monochromatic or nearly monochromatic light and those giving a white light. In the first class only the sodium flame and the yellow-green mercury line ($\lambda = 546.1m\mu$) have been utilized to any extent.

Sodium.—The sodium sources have been summarized by Landolt in Table 4.

TABLE 4
Optical Center of Gravity of Sodium Light Sources

Source of light	Purification	Effective wave length
		$m\mu$
Bunsen flame with NaBr.....	10-cm layer of 9 per cent $K_2Cr_2O_7$ in water.....	592.04
Bunsen flame with NaCl.....	10-cm layer of 9 per cent $K_2Cr_2O_7$ in water.....	589.48
Burner with NaCl or NaBr.....	Lippich filter $K_2Cr_2O_7$ and $U(SO_4)_2$	589.32
Sodium.....	Prism purifications lines D_1 and D_2 only.....	589.25
Landolt lamp with NaCl.....	1.5-cm layer of 6 per cent $K_2Cr_2O_7$ in water.....	588.94
Bunsen flame with NaCl.....	10-cm layer of 9 per cent $K_2Cr_2O_7$ in water and 1-cm layer of 13.6 per cent $CuCl_2$ in water.....	588.91
Landolt lamp with NaCl.....	Unpurified.....	588.06

The various types of sodium lamps have been designed to give the greatest possible intensity consistent with a minimum of attention. In the Pribram¹⁹ lamp fused salt in platinum boats is exposed to a Bunsen flame. When the supply in one boat is exhausted, the boat is withdrawn and a second containing a fresh supply is instantly introduced into the flame. Fairly constant illumination is obtained for a long time. In the Schmidt and Haensch lamp fine platinum wires are bent into a spoon, the melted salt being drawn up to the point by capillarity to the hottest portion of the flame. In the Landolt²⁰ type a Muencke burner (Bunsen lamp with conical wire gauze top and sufficiently strong air supply to cause the inner dark cone of the flame to disappear) is used. Exposed to the flame are two heavy nickel wires around the middle of which nickel gauze is wrapped. The gauze is charged by immersing in melted salt. An intense flame is obtained. The Zeiss lamp is a simple and convenient type. Pumice stone saturated with salt is exposed to a Bunsen flame. The position of the pumice stone with respect to the flame is important and is easily controlled by means of a thumbscrew. For a very intense sodium flame the method of molded sticks of fused sodium carbonate described earlier in this circular is the best.

Mercury.—For the production of the so-called yellow-green line of mercury ($\lambda = 546.1\text{m}\mu$) several types of lamps are available. In all of them advantage is taken of the fact that mercury vapor heated to incandescence by an electric current in a vacuum gives the intense line spectrum previously described. Some type of optical dispersion system must be resorted to in order to separate the desired line. The Arons²¹-Lummer²² type is perhaps the most well known. The mercury is housed in a water-cooled glass vessel. About 60 volts are necessary for satisfactory operation. At this Bureau the fused silica mercury lamps of Heraeus are used. They may be obtained in almost any desired shape. Owing to the relatively high melting point of fused quartz, they can be safely operated at high intensities without water cooling. When it is desired to work at very high intensities a copious current of cold air is blown over the lamp. *Great care must be exercised not to permit the radiation from these lamps to enter the eyes without first passing through glass.*

(2) **White Light—Gas.**—A considerable variety of lamps suitable for white-light sources is available. They are practically all designed either for gas or for electricity. Most of the gas lamps utilize the Welsbach mantle, which is the source most generally used in saccharimetry. The light is

¹⁹ Zs. anal. Chem., 34, p. 166; 1985.

²⁰ Zs. für Instrk., 4, p. 390; 1884.

²¹ Wied. Ann., 47, p. 767; 1892.

²² Zs. für Instrk., 15, p. 294; 1895.

convenient, has considerable intensity, and the radiating surface has a nearly uniform intensity over a sufficiently large area. A ground-glass screen may be used close to the mantle if desired, and is necessary if the lamp can not be so placed as to eliminate a mottled appearance of the field when the telescope is in focus for the analyzer diaphragm.

Electric.—The available electric lamps are of three types—the incandescent lamp for 110 volts, the small straight filament for 6 volts, and the Nernst lamp for 110 or 220 volts. A ground-glass disk, which becomes the new source of radiation, must be used with all three types, and is preferably located as near the radiating surface as the temperature will permit. In Fig. 5 is shown an electric lamp developed at this Bureau.²³ The spiral filament incandescent stereopticon lamp for 110 volts is used. The candle-power is over 100. The area illuminated is ample for the purpose, and the intensity is sufficient. Convenience has been the chief consideration in the design. The base is heavy. The ground-glass disk, A, 38 mm in diameter, is easily removable and is adjustable vertically with respect to the body C. Thus the spiral filament and the disk are kept centered, giving uniform illumination of the disk. The cap B permits the heat to pass off but no light to escape into the room. The height of the lamp is regulated by the rack and pinion D. The center of the disk can thus be accurately set in the axis of the optical system of the saccharimeter. The electrical connection is made at the binding posts E. This lamp has proved very satisfactory. The firm of Schmidt & Haensch have taken advantage of the small size of the 6-volt lamp to mount it in an attachment which fits the metal housing containing the polarizing system of their saccharimeter. The heat developed so near the optical parts is objectionable. The illumination is only fairly satisfactory when the lamp is new, and the efficiency in most cases decreases rapidly with use. The best results are secured with a storage battery to supply the current.

The Nernst glower has been utilized at the Bureau of Standards for some years. It is a very intense source, but difficult to handle. Recently an automatic Nernst projection lamp has been brought out abroad and utilized by the Bureau as a saccharimeter source. The burner carries three large Nernst glowers which require 4 amperes. At 110 volts the candlepower is 500 and 220 volts 1000. This lamp is not recommended except for special work.

²³ Manufactured by Bausch & Lomb, Rochester, N. Y.

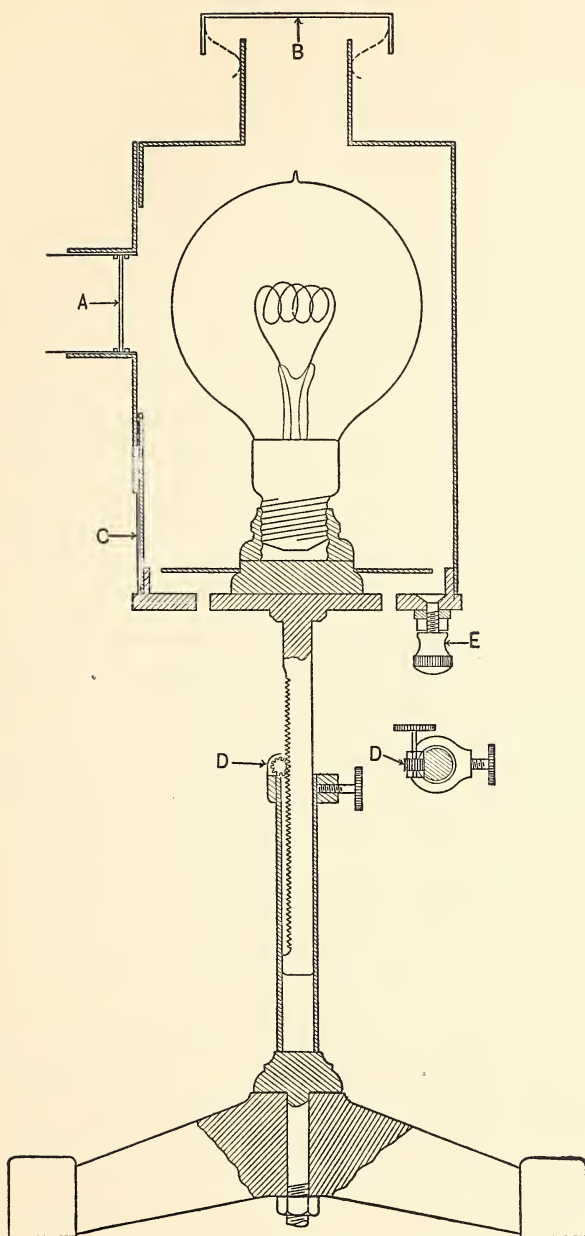


Fig. 5.—Electric light source for saccharimeters

3. QUARTZ CONTROL PLATES

(See Fee Schedule 44)

Quartz control plates will be accepted by the Bureau for standardization with reference to the sugar value. The conditions as to character of mounting, purity of the quartz, etc., given on page 17, are equally applicable here. In standardizing the procedure is to measure the absolute rotation in circular degrees at 20° C on a large precision polariscope, monochromatic light ($\lambda = 546.1\text{m}\mu$) being used. This can be done with great accuracy. The value so obtained is divided by a conversion factor, which gives the value of the plate in sugar degrees for the International Sugar Scale. The checking of a control plate or the scale of a saccharimeter by the use of the standard sugar solution is a difficult measurement. It is never used at this Bureau except in fundamental determinations. The scales of saccharimeters are checked with quartz plates, which are primary standards. Yet even the values of these plates depend on the conversion factor. For the old German or Ventzke sugar scale the value accepted was:

$$100^\circ \text{ Ventzke} = 34.68 \text{ circular degrees for sodium light at } 17.5^\circ \text{ C} \quad (7)$$

The value at 20° C was 34°

When the International Sugar Scale was established, Herzfeld and Schönrock²⁴ redetermined the conversion factor. This factor is not the rotation in circular degrees of the normal sugar solution. It is the rotation in circular degrees of the normal quartz control plate—that is to say, the rotation of a plate which reads 100° on a saccharimeter whose 100° point has been located by the use of a normal sugar solution at 20° C; and a white light source with a bichromate filter. Herzfeld determined the sugar values of a set of 10 control plates. Schönrock measured the rotation of these plates in circular degrees, from which he found

$$100^\circ \text{ Int. Sugar Scale} = 34.657 \text{ circular degrees for} \quad (8) \\ \text{sodium light at } 20^\circ \text{ C}$$

This value is used by the Bureau in all standardizations of saccharimeters and plates unless requested to the contrary. Apparatus so tested should be used with a white light source and the bichromate absorbing solution. In this connection attention is directed to the fact that the importance of maintaining all standardizing bureaus on the same basis of standardization can not be over emphasized.

²⁴ Zs. Ver. Deut. Zucherind, pp. 521-558.

IV. TEMPERATURE CORRECTIONS AND CONTROL

1. QUARTZ WEDGE SACCHARIMETERS

The question of temperature corrections for polarimetric apparatus, as well as for the optically active substances, is a difficult one. The literature on this subject is extensive, but it has not always been a simple matter to select the proper correction owing to the different results secured by various investigators. For the ordinary polarimeter used for measuring absolute rotations no instrument correction is necessary. It may be used at any temperature if care is taken to allow for any zero point shift that may occur. However, a correction is unavoidable for saccharimeters in which a quartz wedge is used to neutralize the rotation of the substance being tested.

The rotation for quartz in the neighborhood of 20° C is given by the following:

$$\alpha_t^D = \alpha_{20}^D + \alpha_{20}^D 0.000143 (t - 20) \quad (9)$$

and since the linear coefficient of expansion of quartz parallel to the optic axis is approximately 0.000007 we have 0.000136 as the specific rotation coefficient. The linear coefficient of expansion perpendicular to the optic axis is 0.000013 and for the so-called nickelin scale on the wedge 0.000018. Thus the total temperature coefficient²⁵ for the ordinary quartz wedge saccharimeter is

$$0.000136 + 0.000007 - 0.000013 + 0.000018 = 0.000148 \quad (10)$$

If the scales are etched on the wedges the scale coefficient becomes zero, and if the scale be of glass we substitute 0.000008 for 0.000018. Since the effect of the expansion coefficient 0.000148 is to lower the reading of the scale with an increase of temperature, the apparent polarization of any substance is lower than it should be and the reading at 20° (S_{20}) is given by the following:

$$S_{20} = S_t + S_t 0.000148 (t - 20) \quad (11)$$

When a quartz control plate is read in a saccharimeter this effect is not completely compensated. The temperature coefficient of the plate is obviously $0.000136 + 0.000007 = 0.000143$. The reading (S_{20}) of the plate is then

$$S_{20} = S_t + S_t 0.000005 (t - 20) \quad (12)$$

The correction given by (12) changes sign if the scale be of glass and is so small at all times as to be negligible in ordinary polarizations.

²⁵ Schönrock; Z. Ver. Deut. Zuckerind. 54, p. 521.

2. SUGARS

(a) SUCROSE

The influence of temperature on the specific rotation of sucrose has been studied by numerous investigators, of whom Dubrunfaut²⁶ was the first to discover that the constant decreased with increase in temperature. Unfortunately subsequent determinations of this variation have not shown satisfactory agreement.

In 1896 Schönrock at the Reichsanstalt carried out an elaborate investigation and found for the specific rotation

$$[\alpha]_D^t = [\alpha]_D^{20} - [\alpha]_D^{20} 0.000217 (t - 20) \quad (13)$$

Later he found that for the normal sugar solution ($p = 23.701$) the temperature coefficient was independent of the wave length of the light used, but that it decreased with increase in temperature as follows:

$$10^\circ \text{C}, 0.000242; 20^\circ \text{C}, 0.000184; 30^\circ \text{C}, 0.000121.$$

If a proper temperature correction is to be applied to a polarization it is necessary to add algebraically all the corrections applicable to the conditions under which the polarization is being made. In the ordinary testing of sucrose the solution is made up to volume and read at the same temperature, which in general is not the standardization temperature. It is desirable, therefore, to know the variation in the saccharimeter reading of a near normal sucrose solution per 1°C . The results of different investigators are given in the following table:

TABLE 5

Saccharimeter Temperature Coefficient for Sucrose

Andrews.....	0.0300	Watts and Tempany.....	0.0310
U. S. Coast and Geodetic Survey.....	.0293		
Wiley.....	.0314	Average.....	.0303
Geerligs.....	.0300		

By a summation of the best known values of the separate coefficients which enter into this constant we obtain the value 0.0348, which compared with 0.0303 is reasonably close. The value varies slightly for individual instruments. The polarization in sugar degrees at 20°C (S_{20}) of an approximately normal solution of sucrose made up and polarized at the same temperature ($t^\circ \text{C}$) is given by the following:

$$S_{20} = S_t + S_t 0.0003 (t - 20) \quad (14)$$

Equation (14) is sufficiently accurate for all ordinary polarizations irrespective of type of tube or scale.

²⁶ Ann. Chim. phys. (3), 18, p. 201.

If the solution be made up to volume at 20°, but is polarized at another temperature, all apparatus being at that temperature, (14) is no longer applicable. Under these conditions the temperature coefficient of the normal sucrose solution alone is given by Schönrock as 0.000469, while that of the saccharimeter, as previously shown, is 0.000148. If a glass tube be used we have as the total temperature correction—

$$0.000469 - 0.00008 + 0.000148 = 0.000609 \quad (15)$$

The polarization in sugar degrees at 20° C (S_{20}) of the near normal solution of sucrose is therefore given by (16).

$$S_{20} = S_t + S_t \cdot 0.000609 (t - 20) \quad (16)$$

Equation (16) obviously holds only while the number of grams of sugar in 100 g of the solution remains unchanged.

(b) MIXTURES

The coefficient 0.0003, in equation (14), having been determined for the normal weight of sucrose should be applied with considerable care. It has, however, long been a widespread practice to apply it to all sorts of saccharine products, with the result that a polarization, supposedly accurate, may contain errors of appreciable magnitude. If the solution does not read approximately 100° S, the correction to give the reading at 20° C should not be obtained by multiplying 0.03 by the difference in temperature—a common practice. In general no great error will be introduced by following this procedure provided the polarization is above 85° S. Nevertheless the better and safer practice is to solve equation (14), thereby correcting for the difference in sucrose concentration from the normal solution.

An even more widespread practice has been to apply (14) to sugar polarizations without regard to the associated impurities. This is particularly true of raw sugars and molasses which contain appreciable quantities of invert sugar. Of the constituents of invert sugar, the dextrose has a negligible temperature coefficient, while the levulose has a very large coefficient, and in such a direction that the positive rotation of the mixture tends to increase upon elevation of temperature.

It is therefore manifestly erroneous to apply a pure sucrose temperature coefficient to a mixture unless all the substances, except sucrose, are present only in such small quantities that the error introduced is negligible.

For the temperature correction of the better grades of raw sugar the temperature formulas (14) and (16) give results which are sufficiently accurate, but if they are applied to low-grade products errors are introduced. Raw

sugars may be considered as mixtures of pure sucrose and cane molasses. To correct the whole mixture for the effect of temperature change, it would be necessary to apply the resultant coefficient obtained by combining the two separate values, taking into consideration the relative quantities of the two and the constitution of the particular molasses which contaminates the sample. Dr. C. A. Browne²⁷ has done this and shows that the temperature coefficient varies in almost direct proportion to the content of molasses. It is in general incorrect to apply this computed correction because of possible individual variation in the constitution of the molasses. Accordingly Browne advises the omission of the temperature correction for low-grade samples. He has computed an average coefficient for large numbers of samples of raw sugar which may be determined according to the polarization. Thus, for cane products, the coefficient is 0.0015. It is seen from this that at 80° the coefficient becomes zero and for lower grades it becomes positive instead of negative. If individual variations did not occur this correction would be a useful one, but as it stands it merely serves to show the possible error of applying equation (13) to low-grade sugar. For beet products the coefficient is 0.0006

3. THERMOSTATS

(a) WATER

The satisfactory control of temperature in polarimetric work is an important and troublesome subject. In general two types of thermostats have been found sufficient at this Bureau, for saccharimeter work, including most research problems. For accurately making up solutions to volume at a desired temperature a water thermostat is used which gives extremely close regulation. It consists of a cylindrical vessel about 40 cm high and 50 cm in diameter nearly filled with water. A copper coil through which ice water flows is placed in the bottom and serves to cool the bath, if necessary, to a fraction of a degree below the desired temperature. The flow of ice water is regulated closely by means of a long arm stopcock. A coil of fine enameled wire, carrying a small current at low voltage, is immersed in the water near the sides of the vessel and serves to raise the temperature to the proper degree. When this point is reached a mercury contact operated by a toluene coil, also immersed in the water, closes a relay circuit and throws the current off the heater. A small fan near the bottom of the bath keeps the water in constant motion, insuring an even temperature throughout. A perforated metal shelf serves to hold the flasks, the perforations allowing free circula-

²⁷ J. Ind. Eng. Chem., 1, p. 567.

tion of the water. The temperature is read from an accurately standardized thermometer immersed in the bath. Electrolysis is minimized by using alternating current. On account of the high specific heat of water and the very narrow limits of temperature for which the heater was designed the inertia of the system is made very small, the maximum variation of the temperature from 20°C being not more than 0.01°C .

(b) AIR

For controlling the temperature at which the polarizations are made a thermostat of relatively liberal dimensions and with a wide range of control is utilized. The dimensions of the room are as follows: Height, 2.5 m width, 2 m; length, 2.5 m. The walls are made double in order to minimize conduction of heat to or from the outer room.

The temperature is controlled by means of a brine coil and an electric heater. The latter consists of iron wires wound upon a porcelain insulated frame. It is suspended just below a false ceiling, and the flow of current is controlled by means of a mercury contact, actuated by the change in volume, with the temperature, of kerosene contained in a small copper tube. This tube is wound about the room some distance away from the walls. The brine coil is contained in a small closet, which has an opening at the bottom and one at the top. A fan draws the warm air in at the bottom and forces the cold air out above the false ceiling, which is full of holes. This false ceiling insures an even distribution of the cold air throughout the whole room.

The operation is as follows: The fan is started which forces air over the brine coil and out through the holes in the false ceiling into the room. As soon as the temperature sinks slightly below that for which the thermostat has been set, the kerosene, contracting, causes the mercury contact to open the circuit through a small relay; this operates a heavy current relay, which throws the current on the heater and the room begins to warm up. When the desired temperature is reached, the mercury contact closes the relay circuit and throws off the current from the heater. By this means the temperature is kept very nearly constant, the maximum variation at the working level being only about two or three tenths of a degree. Thus if set for 20°C , the temperature of the air in the room would alternately rise and fall to about 20.15° and 19.85° , respectively. This variation is caused by the inertia of the system, which is necessarily rather large, the system being designed to operate anywhere between 15°C and 35°C . The heater takes about 7 or 8 amperes at 120 volts. This thermostat is found to be very

satisfactory, as it operates indefinitely and requires almost no attention after it has once been adjusted.

The saccharimeters are placed upon a table at a convenient height. One instrument is incased in an asbestos-lined box. This so retards any change of temperature of the instrument that, with the room operating to within two or three tenths of a degree, no change whatever can be noted on the thermometer inside the instrument case after equilibrium has once been reached. The illumination for the instruments is secured by placing suitable light sources (Welsbach mantle, electric-glow lamp, etc.) just outside the room, allowing the light to pass through the wall by way of a small glass window just large enough to cover the end of the polarizer. Incandescent lights for reading the scales, thermometers, etc., are operated by suitable switches placed within convenient reach of the observer.

V. POLARISCOPE TUBES

(See Fee Schedule 44)

1. TYPES

(a) ORDINARY

There are at present available a variety of polariscope observation tubes, each designed to give satisfactory results under certain conditions. In making a selection the user must be guided by his own peculiar needs. In general all tubes must fulfill three requirements that are essential and which, if not fulfilled by the maker, can not be remedied by the user. They are parallel ends, accurate length, and accurate centering of the axis of the tube with all points of support. The type for ordinary polarizations at temperatures not far removed from 20° C is the simplest and, unfortunately, has received least consideration. Its design should have had careful study, even to the slightest detail. This is essential owing to its widespread and constant use both for scientific and commercial purposes.

It has the same diameter of bore for its entire length and small cover glasses closing its ends. It is generally made entirely of brass, although many are in use in which the body is of glass, to which are cemented metal caps for carrying the cover glasses.

Glass tubes are little used except when polarizing acids or other corrosive liquids. Not only are they easily broken by impact, but the metal end pieces, to which the cap screws, must be mounted with wax. If placed in warm water for cleaning, or even on warm days, the wax softens. The metal tubes have always been constructed from tubing with thin walls which a slight blow is sufficient to bend, thereby causing a change in length

and permanently ruining the tube. In the United States customs and many other laboratories it is necessary that a tube be available which will stand the most arduous usage. In addition there are important defects in the design of the ordinary tube. Some effort has been made to partially overcome several of these defects, but only in glass, a material which for reasons previously stated can not be satisfactorily used. The diameter of the bore has been too small. The diaphragming in the modern saccharimeter is designed to give the highest possible illumination of the field. To utilize this, as well as eliminate the undesirable "halo" incidental to the ordinary tube, it is necessary that the bore have a diameter of not less than 9 mm. Considerable time is lost in filling owing to the fact that the tube must be so completely filled that no trace of air remains. Also the weight is carried upon the caps which contain the cover glasses. If the tube be rotated in the trough of the instrument the caps may be tightened and cause double refraction in the cover glasses, which has the effect of a change in rotation.

(b) BATES

In order to overcome the prevalent defects in the theoretical design, as well as to secure a tube suitable for severe usage, this Bureau has brought out the new Bates²⁸ type of tube shown in Fig. 6. It will be observed that the weight is carried upon two shoulders, which are integral parts of the tube, and not upon the caps, thereby eliminating all danger from turning while in the trough of the instrument. The bore is 9 mm, permitting the utilization of the full aperture of the polarizing system. This also reduces to a minimum the light depolarized by reflection from the walls of the tube. The field of the instrument thus appears for the first time as a bright, sharply defined circle with no overlying haziness, and the reading can be made with increased accuracy. Both ends are enlarged with all the attendant advantages, yet but one size of cover glass and washer is required. The walls are unusually heavy, eliminating all danger from bending.

(c) SPECIAL

There are in addition a number of tubes designed for special purposes. The Schmidt and Haensch water-jacketed type permits of holding the solution at a nearly constant temperature. An opening midway between the ends allows a thermometer to be inserted into the solution. Landolt has designed a glass tube with one end enlarged and sliding caps, which fasten with bayonet catches. The Pellet tube has two side openings, permitting of filling and emptying without removing from the saccharimeter.

²⁸ Manufactured by Bausch & Lomb, Rochester, N. Y.

Much time can be saved by this scheme on certain kinds of polarizations where accuracy is not the first consideration. Yoder has produced a so-called volumetric tube. The graduation is marked upon a side connection joined to the middle of the tube. Often when polarizing at temperatures below the dew point the moisture condenses on the cover glasses. Wiley²⁹ has overcome this by an ingenious desiccating cap, which carries calcium chloride and screws to the end of the polarization tube.

2. TEMPERATURE CORRECTION

The length of any tube at any temperature is given by the following:

$$L_t = L_{20}[1 + \beta(t^\circ - 20^\circ)] \quad (17)$$

where L_{20} is the length at 20°C and β is the coefficient of expansion of the material of which the tube is made. For glass $\beta = 0.000008$, and for brass $\beta = 0.000019$. From (17) for $L_{20} = 200$, $L_{30} = 200.016$ for glass and 200.038 for brass. It is thus evident that the errors resulting from changes in length for tubes from either material are negligible in ordinary use.

3. ACCURACY

All types of tubes are accepted by the Bureau for test. The limit of accuracy, unless by special arrangement, is $\pm 0.04 \text{ mm}$.

VI. COVER GLASSES

(See Fee Schedule 44)

Glass which is not free from strain is doubly refractive and on this account can never be used between the polarizing and analyzing systems of a polariscope. It is thus of the greatest importance that cover glasses be thoroughly annealed. A strain in the glass is in effect a rotation. Many baffling differences in polarizations are due to cover-glass strain. There is no infallible method of detecting this trouble after the glass is in use. After a setting has been made, it is a good plan to rotate the tube while in the instrument; if the halves of the field show variations in intensity, strain exists in one or both cover glasses. The only safe procedure is to use tested glasses and as little pressure as possible on the caps. Strains frequently arise from poorly fitting washers. Washers should be made from pure rubber, soft and flexible, and lie flatly and evenly in the cap. Once a glass has been strained it should not be used for two days or longer. All cover glasses must have plane, parallel surfaces, free from scratches and should never be less than

²⁹ J. Am. Chem. Soc., 18, p. 81.

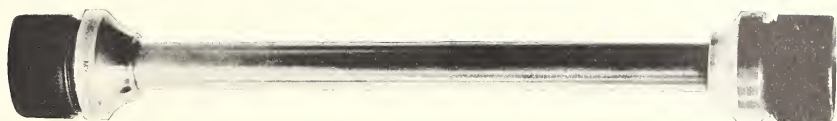


Fig. 6.—*Bates polariscope tube*



Fig. 7.—*Flask for sugar testing*

1 mm thick. A thickness of 2 mm is preferable. The Bureau will accept cover glasses for test. The necessity for optically perfect glasses seldom receives the attention its importance demands.

VII. FLASKS ³⁰

(See Fee Schedule 23)

1. SPECIFICATIONS

(a) MATERIAL AND ANNEALING

The material should be the best quality of glass, transparent, and free from bubbles and striæ. It should have small thermal hysteresis and should adequately resist chemical action. All flasks should be thoroughly annealed before being graduated.

(b) DESIGN

The cross section of the neck must be circular, and the shape of the flask must be such as to admit of complete emptying and drainage from the whole interior surface at the same time. The bottom of the flask should be slightly concave upward, and should be of sufficient size to enable the flask to stand on a surface inclined at an angle of 15 degrees to the horizontal. The neck must be cylindrical for at least 1 cm on each side of every graduation mark, but may be enlarged in the form of a bulb between graduation marks (for example, Giles flasks). At the graduation mark the inside diameters of the neck of the flask must be within the limits given in Table 6.

TABLE 6

Diameters of Necks of Flasks

Capacity of flask (in cc) up to and including.....	25	50	100	200	250	500	1000	2000	3000	4000	5000	6000
Maximum diameter (in mm).....	8	10	12	13	15	18	20	25	30	35	40	45
Minimum diameter (in mm).....	6	6	8	9	10	12	14	18	20	22	25	30

(c) GRADUATION MARKS

The graduation marks must be of uniform width, finely but distinctly etched, must be perpendicular to the axis of the flask, and must extend completely around the neck.

On flasks having a capacity of 100 cc or less the graduation mark shall be not less than 3 cm from the upper end nor less than 1 cm from the lower end of the neck; and on flasks having a capacity of more than 100 cc the graduation mark shall be not less than 6 cm from the upper end nor less than 2 cm from the lower end of the neck.

³⁰ For further details in regard to volumetric apparatus, see B. S. Circular No. 9.

(d) UNIT OF VOLUME

The unit of volume employed is the liter, which is defined as the volume occupied at the temperature of its maximum density (4°C) by a quantity of pure water having a mass of 1 kilogram. The water is under a pressure of 760 mm of mercury, and the weighings are reduced to vacuo. The one-thousandth part of the liter, called the milliliter (ml) or the cubic centimeter (cc), is also employed as the unit of volume.

(e) STANDARD TEMPERATURE

Twenty degrees centigrade has been adopted by the Bureau as the standard temperature for volumetric apparatus, and an extra charge is made for testing apparatus graduated for use at other temperatures.

(f) INSCRIPTIONS

Each flask must bear, in permanent and legible characters, the capacity in liters or in cubic centimeters, the temperature at which it is to be used, the method of use, i. e., whether to contain or to deliver, and an identification number. In the case of flasks with stoppers the stopper must bear the same number as the flask.

A suitable arrangement of the inscription is as follows:

No. 134
Contains
100 cc
at 20°C

2. TOLERANCES

The tolerances for flasks of various sizes are shown in Table 7.

TABLE 7

Tolerances for Flasks

Capacity less than and including—	Tolerance		Capacity less than and including—	Tolerance	
	If to contain—	If to deliver—		If to contain—	If to deliver—
cc	cc	cc	cc	cc	cc
10	0.01	0.02	1000	0.30	0.50
25	.03	.05	2000	.50	1.00
50	.05	.10	3000	.75	1.50
100	.08	.15	4000	1.0	2.0
200	.10	.20	5000	1.2	2.4
300	.12	.25	6000	1.5	3.0
500	.15	.30			

(a) PRECISION STAMPS

Flasks tested by the Bureau of Standards and found to comply with the foregoing specifications will be given the official precision stamp of the Bureau. The stamp consists of the letters "U. S." and the year in which the test is made, surrounded by a circle. Thus for the year 1914 the stamp will be:



The stamp will be placed on the neck of the flask above the graduation mark.

(b) SUGAR TESTING FLASK

The type of flask used in the United States Customs Service is shown in Fig. 7. It is especially designed for sugar polarizations and is described in the Regulations Governing the Weighing, Taring, Sampling, Classification, and Polarization of Imported Sugars and Molasses, 1908, as follows: "The flasks shall have a height of 130 millimeters; the neck shall be 70 millimeters in length and have an internal diameter of not less than 11.5 millimeters and not more than 12.5 millimeters. The upper end of the neck shall be flared, and the graduation marks shall be not less than 30 millimeters from the upper end and 15 millimeters from the lower end of the neck." These flasks are not in accordance with the Bureau of Standards specifications, in that the diameter of the neck allowed is too large. They will not, therefore, be given the precision stamp of the Bureau. But when found to meet the Bureau specifications in other respects they will be stamped with the letters "B. S." and the year in which the test is made. Thus for the year 1914 the stamp will be:

B. S.

1914.

In this type of flask the neck, while smaller than the ordinary 100 cc commercial flask, is made slightly larger than the Bureau requirements for a flask of this size in order that the neck shall not become clogged when the sugar is being introduced into the flask. The upper end is provided with a small lip to facilitate pouring. The height of only 130 mm minimizes the dilution of the solution by drops of water on the upper part of the neck and gives a length which readily permits the flask to be closed with the thumb while the forefinger rests on the bottom, thereby facilitating a thorough mixing by shaking, with no loss by spilling.

(c) SPECIAL

Other varieties of flasks designed for special purposes are shown in Fig. 8. Some of these are taken from Browne's Handbook of Sugar Analysis, p. 165.

No. II has low center of gravity insuring greater stability.

Nos. II and III have double graduation marks which are of use for any work where one volume of liquid is diluted to a different volume. This is frequently done in inversion and clarification operations.

No. IV permits the convenient transfer of solid material.

No. V is the diagram of a flask designed at this Bureau for work of high precision. The inside diameter of the graduated neck is 5 or 6 mm. The enlarged portion of the neck has for its purpose the complete mixing

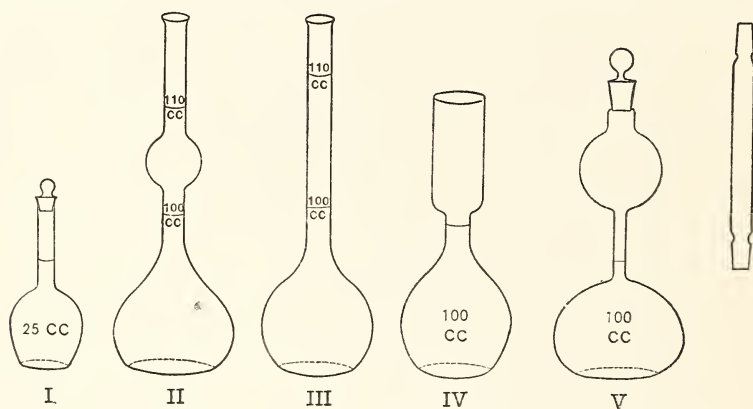


Fig. 8.—Special flasks

of the contents of the flask without the use of the thumb or a ground stopper, both of which may prevent small quantities of liquid from mixing with the remainder. Before making to volume this bulb should be dried inside by a current of filtered air. The glass tube fits into the grinding of the flask and enables a transfer from flask to polariscope tube without exposure to the air and a consequent evaporation of the solution. For this purpose the polariscope tube is fitted with a tubulature and grinding. With this apparatus it is possible to calibrate the flask and reproduce the volume of liquid with an accuracy of 0.002 cc.

(d) CORRECTION TABLES

Tables 8 and 9, page 116, are given for the convenience of those who wish to verify the graduation of volumetric apparatus. More complete data for this purpose will be found in Bureau Circular No. 19.

VIII. THERMOMETERS³¹

(See Fee Schedule 10)

1. GENERAL

Thermometers should be made of a suitable hard glass having small "zero depression" and small thermal hysteresis. Among the glasses best fulfilling these requirements are 16^m Jena normal glass, 59^m Jena borosilicate glass, and French hard glass. It is only important that the bulbs of the thermometers be made of a suitable hard glass; for the stem of the thermometers a softer glass with white enamel back may be used. For ordinary laboratory thermometers, when an order of accuracy of 0.°02 or 0.°03 C is sufficient, the stem should be so graduated by the maker that the indications of the thermometer will be in close agreement with the indications of the gas thermometer, which is taken as the standard.

It is highly desirable that the ice point (0° C or 32° F) be found on the scale so that variations in the volume of the bulb can be easily detected and allowed for. The divisions on the stem should be fine and clear, the width of the graduation marks in no case exceeding 0.2 of a scale division, and should be numbered at such frequent intervals and in such a way that identification of any graduation mark is not unnecessarily difficult. Where the thermometers are provided with metal backs which carry a graduation, the stem of the thermometer should nevertheless be graduated. The thermometer should be securely and firmly fastened and should have a fiducial mark on the stem coinciding with a mark on the metal back, so that any relative displacement may be controlled. If the thermometer is of the inclosed scale (Einschluss) type, such fiducial mark should be found on the outer glass tube inclosing the scale and capillary stem of the thermometer. The bore of the stem and the spacing of the graduation marks should be uniform and free from such irregularities as would produce errors in the indication by amounts exceeding the limits otherwise set by the type of thermometer.

2. LABORATORY AND SPECIAL THERMOMETERS

Under this head may be broadly grouped most of the thermometers of the usual types, including secondary, and working standards, whose order of accuracy is 0.01° or 0.02° C, and ordinary thermometers whose order of accuracy is 1 or 2°. Illustrations of special thermometers are maxima and minima thermometers, calorimetric, hypsometric, deep-sea, and other ther-

³¹ Further details of the construction and precautions in use of mercurial thermometers are given in B. S. Circular No. 8.

mmeters used for special purposes. For information concerning the testing of high temperature, industrial, calorimetric, and Beckman thermometers, see Bureau of Standards Circular No. 8.

IX. WEIGHTS ³²

1. SUGAR WEIGHTS

It is generally advantageous to have special 26-g or 13-g weights for weighing out sugar samples. For this work the Bureau recommends that the ordinary screw-knob type of weights be avoided in favor of one in which the knob forms an integral part of the weight. Such weights may be strictly one-piece weights or they may have a cavity on the upper side closed by a driven plug or pin of brass or other hard metal. The working standards should conform to the Bureau's requirements for class B. The reference standards (i. e., those used only for checking the working standards) should conform to the requirements for class A. The maximum error allowed in both classes is 2 mg on the 26-g weight and 1.5 mg on the 13-g weight. Class B weights may have the adjusting plug or pin mentioned above, and when tested at this Bureau no corrections will be given, but they will be certified merely as conforming to the requirements of this class. Class A weights must be strictly one-piece weights, and when tested at this Bureau the actual correction will be certified for each weight, and they will be tested for constancy over a period of three months.

2. ANALYTICAL WEIGHTS

A good grade of analytical weights should be accurate enough for this work, but it is not safe to rely on them unless they are tested. For work that requires considerable accuracy in the weighing the weights should conform to the Bureau's requirements for class S. This class includes practically all sets sold as high-grade analytical weights, if they are adjusted to the proper degree of accuracy. The maximum errors allowable range from 0.5 mg on the 100-g weight to 0.1 mg on the 1-g weight and 0.02 mg on the 10-mg weight. For less accurate work the weights may have errors from 30 mg on the 100-g weight to 2 mg on the 1-g weight and 0.15 mg on the 10-mg weight.³³ The list of tolerances is given in Table 10. When

³² Full details on classification, requirements, and testing of weights suitable for various purposes are given in Circular No. 3, from which parts of this section are either copied or adapted. This circular may be had on application. In purchasing weights the denominations, the type of weights, and the fact that they must conform to the Bureau's requirements for weights of a certain class are generally the only specifications that are necessary. Manufacturers and dealers are in possession of these requirements or can readily procure them.

³³ See column headed class C.

weights of either class are tested at this Bureau, the actual correction for each weight will be certified. The use of weights constructed like those recommended for the "sugar weights" would introduce a distinct gain in reliability.

3. REFERENCE STANDARDS

Weights are liable to change. They can not be used without a certain amount of wear, which must ultimately make an appreciable change in their values. Ordinary analytical weights sometimes suffer serious change from the oxidation of adjusting material placed in the cavity under the knob. Weights must therefore be retested from time to time according to the nature of the weights and of the work for which they are used. Reference standards are therefore needed, since it is seldom advisable to send the weights to this Bureau as often as would be needed. There is no gain in the purchase of complete sets for this purpose, when this is done at the expense of quality, as must usually be the case. A set of working standards can readily be tested by intercomparison of the weights among themselves if one or two reference standards are available on which to base the calibration. The Bureau will gladly furnish information in regard to series that are much better than the ones generally used, and yet involve no great amount of additional labor. Probably the best denominations for reference standards would be one 100-g or 50-g weight, one 1-g weight, one 10-mg weight, one 26-g weight, one 13-g weight. The 1-g weight should be made of platinum, as it is the starting point for the determination of the milligram weights.

For the best reference standards the Bureau recommends one-piece weights. Gold-plated Tobin bronze weights are the most satisfactory ones now available for this purpose for weights above 1 g. Weights having a hard-metal driven plug, as recommended for the working standards for "sugar weights," would rank next. Standards for the analytical sets should conform to the requirements for class S and be tested under that class.³⁴ Reference standards for the "sugar weights" should come under class A, as stated above.

4. CERTIFICATION

Sugar weights and analytical weights are among the weights tested by this Bureau, but the rougher weights are not regularly accepted for test. Corrections will be certified to the degree of precision indicated in Table 10.

³⁴ The same kind of weights, but less accurately adjusted, may be obtained as class A and class B weights. For extreme accuracy (seldom, if ever, needed in weighings for polarimetry) when careful corrections must be made for the buoyant force of the air, only one-piece weights can be relied upon, and the volume of each weight must be determined. This requires that the weights come under class M.

The corrections for the platinum and aluminum fractions of a gram will be given both on the basis of actual mass and on the basis of their apparent weight in air against brass standards. To assist in the identification of the weights the test number assigned to the weights by the Bureau of Standards will be stamped on the bottom of the box provided for keeping them, thus:

B. S. Test No. 4978

The shipping case or the inner wrappings will always be sealed when tested weights are shipped from the Bureau.

5. PACKING

A great many of the milligram weights that are packed under the glass covers in the regular boxes reach the Bureau bent or otherwise damaged. For this reason greater care should be given to the packing of these weights and sufficient extra packing should be used to hold the glass cover securely in place.

X. OPTICAL ACTIVITY IN ORGANIC COMPOUNDS

The phenomenon of optical activity or the rotation of the plane of polarized light is inherent in many substances. These substances exhibit the property either in the crystalline state with which the cause of the activity is closely connected or while in liquid or dissolved state, in which case the activity is connected with the molecular configuration. This latter class is limited to the carbon compounds.

The advances in stereochemistry show that optical activity occurs when the "asymmetric" carbon atom is present. According to this conception, which was originated by Van't Hoff and Le Bel, the four valences of carbon are situated spatially at the four corners of a regular tetrahedron. If these four valences be satisfied by combination with four different radicles or groups of elements, there are found to be two different methods of arrangement which can not be made to coincide with each other. This fact may be very easily demonstrated diagrammatically by drawing a tetrahedron having three apexes in the plane of the paper and attaching four arbitrary but different radicles to the four corners. If now the mirror image of this diagram be drawn it will be evident that the two arrangements can not be made to coincide. This fact would not be true if any two of the four attached radicles were the same. It has been shown experimentally that whenever the asymmetric carbon atom occurs there is usually to be found another modification exactly similar in all its properties except an equal but opposite rotation of polarized light. Such a substance would be represented graphi-

cally by the mirror image of the former and the two are called optical antipodes. If the rotation occurs toward the right it is called a dextro-rotatory, substance designated by d —if to the left it is called a laevo-rotatory substance, designated by l .

Organic substances such as the sugars which are built up in the cells of organisms are almost invariably dextro or laevo-rotatory, seldom mixtures of the two. Substances which have been synthesized in the laboratory are usually equal mixtures of the two antipodes and the rotation is thus neutralized. In many cases these mixtures may be separated into their constituent parts. The simpler sugars, pentoses and hexoses, frequently have from three to five asymmetric carbon atoms, the more complex, the bioses and trioses may have twice or three times this number. It is thus evident that very great diversity in rotatory power is possible.

XI. TESTING OF RAW SUGAR

1. SAMPLING AND MIXING OF SAMPLES

The importance of a correct method of sampling raw sugar can not be overestimated. If this step is carelessly or erroneously carried out, the most careful work on the part of the chemist is vitiated. The details of the process of sampling should be arranged with two requirements kept in view: (1) The sample should be thoroughly representative of the package; (2) after the sample is taken it should undergo no change until used for analysis.

In order to obtain a representative sample, the sampling instrument called the "trier" should be plunged into the middle of the package and drawn out filled with sugar. If the trier has the correct length and the sampling is skillfully done, all the layers of sugar in the package are represented in the sample. Great care should be exercised to avoid taking a surface sample, since the variations caused by drying or absorption of moisture have their maximum effect at the surface. The dimensions of sugar triers are given on page 101 of this circular in the Regulations of the United States Treasury Department relative to the sampling of imported sugars.

If the sugar is contained in barrels or other wooden packages, it should be sampled by running the long trier or barrel trier diagonally through the package from chime to chime. In case molasses has drained to the bottom of the package especial care must be taken that the sample be taken symmetrically.

In procuring samples from large shipments of sugar it is advisable to take samples from every package, mix the large quantity of material thoroughly, and resample the mixture for analysis.

In order to prevent a change in the composition of the sample taken, the total contents of each trier should be emptied into a tightly covered receptacle and the trier left clean for the next sample, the whole operation being completed within a few seconds. The subsequent mixing and resampling should be conducted in such manner as to avoid unnecessary exposure to the atmosphere. These precautions are needful because of the great tendency of raw sugar to change its moisture content when exposed to the air.

A large proportion of the impurities in raw sugar are in the form of molasses clinging to the surface of the crystals, and the evaporation or absorption of moisture may be very rapid. The action of an absorbing material during mixing (such as the brown paper, which is frequently used) may affect the polarization very markedly by wiping the molasses from the surfaces of the crystals. If samples are to be preserved before analysis or for subsequent reference, they should be placed in tightly sealed containers in order to avoid loss by evaporation.

Further details as to the correct procedure in sampling will be found in the United States Treasury Regulations (Arts. 3-22), which are printed as an appendix to this circular.

2. DUTCH COLOR STANDARD

The Dutch Color Standard consists of a series of crystallized sugar samples of approximately equal gradations of color ranging from No. 7 which is very dark to No. 25 which is almost white. The color grade of any given sample is determined by a comparison with the standard series, prepared by an establishment in Holland for the sugar trade. The standards are contained in sealed bottles, but are renewed at least once a year because of the tendency for the colors to change.

No. 16 Dutch Standard is the technical color distinction in the United States between refined and raw sugar.

3. DIRECT POLARIZATION

(See Fee Schedule 45)

Much of the analytical work on which is based not only the chemical control during extraction and refinement but also the adjustment of commercial transactions, consists of the so-called direct polarization. The term "direct polarization" may be defined as the reading in the polariscope of 26.000 g of the sample in 100 true cubic centimeters of solution at 20° C with only such substances removed as impede the passage of light. In dis-

inction to the direct polarization is the Clerget or double polarization method which indicates the per cent of sucrose. The direct polarization is the resultant optical rotation of all optically active substances present in the sample. In high grades of sugar the Clerget and direct polarizations give results not far apart, but in low grades of sugar and in molasses the difference may become considerable.

The direct polarization is executed in a great variety of ways with respect to the details of manipulation.

The following method is the one most conveniently used in commercial work. It gives a value which is somewhat in error, but if it is carefully carried out the results are sufficiently uniform to adjust trade relations and to control manufacture. The sample is thoroughly mixed, all lumps broken up, and weighed very quickly into the capsule, great care being taken to prevent moisture change during weighing by hastening the process as much as due accuracy will permit. If the polariscope is read to only 0.05 S it is useless to weigh more closely than 0.015 g, and it is distinctly advantageous not to exceed this precision because the extra time involved allows increased opportunity for moisture change. The sample is then washed into a 100 true cubic centimeter flask and dissolved. The transference to the flask may be conveniently accomplished by the use of a funnel. This will allow the use of a narrower necked flask without any greater expenditure of time. The sugar is then brought into solution by a few minutes' shaking, a shaking machine being convenient if a large number of samples are to be done. At this point the clarifying agent must be added. The method of clarification depends on the nature and amount of impurities present. The universal principle to be applied is to add the minimum quantity necessary to clarify, whatever the agent added. In a large proportion of samples, clarification will consist of the addition of 1 to 3 cc of basic lead acetate solution followed by 1 or 2 cc of alumina cream. Frequently a foam appears on the surface of the meniscus which renders it impossible to adjust the volume accurately. This may be dispersed by blowing on it a small quantity of alcohol or ether from an atomizer.

To obtain good definition while making up to volume the bottom of the meniscus should be made to appear dark by reflection of the finger or section of a rubber tube placed a few millimeters below the mark on the neck of the flask. The meniscus shaded in this way should be made tangential to the upper edge of the graduation mark. It is essential that the temperature of the solution during the process be the same as that of polariscopes, tubes, and quartz-control plates.

For high grades of sugar the temperature correction of 0.03° S for each degree Centigrade removed from 20° C has been calculated for conditions where the whole operation is carried out at the same temperature. This correction is not valid if these conditions are not fulfilled.

The solution is then shaken thoroughly and poured on a filter. The first few cubic centimeters of filtrate are rejected since they are almost invariably made turbid by the passage of a small amount of the lead precipitate through the filter paper. During filtration it should be made an invariable practice to cover the funnels with cover glasses to prevent evaporation of the solution. This important precaution is frequently neglected. The contention that the evaporation is one of the constant errors of this method is not valid, because the evaporation is not constant, but depends on the accidental conditions of temperature, relative humidity of the atmosphere, and movement of air in the room.

In filling the polariscope tube the tube is rinsed two or three times with the solution to be polarized. During this rinsing the filtration jar should be given a rotary motion to stir its contents. This stirring brings the solution to a uniform density, thereby permitting a sharp focusing of the polariscope eyepiece. Care should be exercised to avoid errors due to the physical condition of the tube.

The accepted reading of the polariscope should be the average of at least three settings of the end point, and it is a great advantage to use both eyes for the determination.

Polarization by this method gives a value which is uniformly reproducible. It does not, however, represent the per cent of sucrose, because it does not take into account the other optically active substances which are usually present, nor does it represent the true direct polarization, because the 26 g of substance are not contained in 100 cc solution.

4. CLERGET POLARIZATION

(See Fee Schedule 45)

Owing to the presence of invert sugar besides other optically active substances occurring in raw sugar the direct polarization does not represent the true per cent of sucrose, but rather a resultant of all optically active substances present. The classic method of Clerget takes advantage of the fact that the molecule of sucrose is hydrolyzed in the presence of acid. By this hydrolysis or "inversion" the sucrose molecule is split into two simpler molecules, the one called dextrose or d-glucose and the other levulose or d-fructose. The mixture of equal quantities of the two is called invert sugar. It is upon the readiness with which this split takes place that

Clerget's method depends. Under the conditions which cause the complete hydrolysis of sucrose the other optically active sugars are relatively stable, and therefore the change in rotation is due to the change in sucrose alone.

(a) DETERMINATION OF SUCROSE IN THE ABSENCE OF RAFFINOSE ⁸⁵—OFFICIAL METHOD OF THE ASSOCIATION OF OFFICIAL AGRICULTURAL CHEMISTS.

“Dissolve the normal weight of the substance in water, clarify with lead subacetate, and dilute to 100 cc. Filter and polarize the filtrate at 20° C in a 200-mm tube. The reading obtained is the direct reading or polarization before inversion. Free 50 cc of this filtrate from lead by treating with anhydrous sodium carbonate, sodium sulphate, or potassium oxalate, place in a 100 cc flask, and add 25 cc of water. Then add, little by little, while rotating the flask, 5 cc of hydrochloric acid, containing 38.8 per cent of the acid. Heat the flask after mixing in a water bath which is at 70° C. The temperature of the solution in the flask should reach 67° to 69° C in two and one-half to three minutes. Maintain a temperature of as nearly 69° as possible during seven to seven and one-half minutes, making a total time of heating of 10 minutes. Remove the flask and cool the contents rapidly to 20° C and dilute to 100 cc. Polarize this solution in a tube provided with a lateral branch and a water jacket, passing a current of water around the tube to maintain a temperature of 20° C.

“The inversion may also be accomplished as follows: To 50 cc of the clarified solution, freed from lead, add 5 cc of a 38.8 per cent solution of hydrochloric acid and set aside during a period of 24 hours at a temperature not below 20° C; or if the temperature be above 25° C set aside for 10 hours. Make up to 100 cc at 20° C and polarize at that temperature. This reading must be multiplied by two, which gives the invert reading. In case it is necessary to work at a temperature other than 20° C, which is allowable within narrow limits, the volumes must be completed, and both direct and invert polarizations must be made at exactly the same temperature. The sucrose is calculated by the following formula:

$$S = \frac{100 (P - I)}{142.66 - \frac{T}{2}} \quad (18)$$

S = per cent of sucrose.

P = direct reading.

I = invert reading.

T = temperature at which readings are made.

⁸⁵ Bull. Bur. Chem., 107, p. 41.

(b) DETERMINATION OF SUCROSE AND RAFFINOSE

[Of value chiefly in the analysis of beet sugars]

"If the direct reading be more than 1° higher than the per cent of sucrose, as calculated by the formula given above, raffinose is probably present, and sucrose and raffinose should be calculated by the following formulæ of Creydt:

$$S = \frac{0.5188 P - I}{0.8454}; R = \frac{P - S}{1.85} \quad (19)$$

5. INVERTASE METHOD

(See Fee Schedule 45)

Occasionally there occur in samples of saccharine products substances besides sucrose whose optical activity is changed by the acid hydrolysis under the same conditions which cause the inversion of sugar. If an estimation of sucrose is desired, any such change introduces an error. For many such cases the inversion by invertase is more suitable in that it confines its action to sucrose. Invertase is a substance of unknown composition belonging to the class of enzymes and is synthesized only in the tissues of living organisms. Its activity in the inversion of sucrose is due to true catalysis, since it is in no way diminished or altered during the course of the reaction. It is destroyed by boiling or by the addition of strong acids or alkalis. Invertase has never yet been obtained in the pure condition, because it does not crystallize from its solutions.

C. S. Hudson⁸⁶ gives a method for its preparation and use. From this article the following is taken:

To prepare a stock solution of invertase break up 5 pounds of pressed yeast, which may be either baker's or brewer's yeast, add 30 cc of chloroform to it in a closed flask, and allow it to stand at room temperature over night. By morning the solid mass will have become fluid and it should then be filtered through filter paper, allowing several hours for draining. To the filtrate add neutral lead acetate until no further precipitate forms and again filter. Precipitate the excess of lead from the filtrate with potassium oxalate and filter. To this filtrate add 25 cc of toluene and dialyze the mixture in a pig's bladder or collodion membrane for two or three days against running tap water. The dialyzed solution is colorless, perfectly clear after filtration, neutral to litmus, has a solid content about one-half of 1 per cent, an ash content of a few hundredths of 1 per cent, will keep indefinitely in an ice box if a little toluene is kept on its surface to prevent the growth of micro-organisms, and is exceedingly active in inverting cane sugar. The invertase solution does not reduce Fehling's solution.

The collodion dialyzer may be made by pouring into a clean, dry test tube or other glass vessel of the desired size a collodion solution and immediately pouring the liquid back into the container. The tube is thus left with a layer of liquid clinging to the walls. It is held in an inverted posi-

⁸⁶ J. Ind. Eng. Chem., 2, p. 143.

tion until the evaporation of the solvent leaves the collodion somewhat sticky. It is then filled with water. After a few moments the membrane may be removed from the tube ready for use. If water is added too early, the collodion becomes white and opaque. If it is allowed to become too dry, it is too impermeable.

Invertase has a slight optical activity, which is negligible for any but the most careful work. Its activity is greatly increased by the addition of a small quantity of acetic acid, but too great an excess causes a diminution of activity. With hydrochloric acid the maximum activity occurs at a concentration of one-thousandth normal.

To perform the analysis the normal weight of sugar is dissolved and clarified in the usual way and made up to 100 cc. Filter and polarize. From the filtrate remove the lead by addition of potassium oxalate or sodium carbonate and filter. To 50 cc of the filtrate add acetic acid until the solution is acid to litmus, add 5 cc of invertase solution and complete to 100-cc volume. Add enough toluene to prevent growth of micro-organisms and allow to stand at room temperature over night. Bring the solution to the temperature at which the first solution was read and polarize in a 400-mm tube. Calculate the per cent sucrose by the formula

$$\frac{S - I}{141.7 - \frac{t}{2}} \times 100$$

For a more complete discussion see above reference.

6. CLARIFICATION

All methods of clarification at present available have accompanying disadvantages which necessitate great precautions in order to minimize their effect.

The choice of a clarifying agent depends on the darkness of the sample of sugar to be tested. Those in most frequent use are: 1, Alumina cream; 2, basic lead acetate; 3, animal charcoal. In less frequent use, but having some advantages in special cases, are: 4, Neutral lead acetate; 5, basic lead nitrate; 6, alum solution; 7, sodium hydrosulphite; 8, sodium hypochlorite.

(a) ALUMINA CREAM

Alumina cream is a suspension of aluminum hydroxide $Al(OH)_3$ in water. It is prepared by precipitation from alum or aluminum sulphate solution by means of ammonia. The precipitate is washed free from soluble salts or left unwashed according to the use to which it is to be put.

In case the precipitate is to be washed it is advisable to add the ammonia in slight excess. The washing of the precipitate may be conveniently carried out by suspending the mixture in parchment paper bags in a vessel of water, changing the water in the vessel frequently. Or it may be washed in the usual way on a filter, provided that caution is used to prevent the precipitate from becoming dry. The washing is continued until a portion of the wash water tested with barium chloride shows only traces of dissolved sulphates.

The washed alumina cream may be used either as the sole clarifier for high-grade samples if its action is sufficiently effective or it may be used in conjunction with basic lead acetate. When used together with lead, it increases the clarifying action of the basic lead acetate and permits the use of a smaller quantity than would otherwise be necessary. When the washed alumina cream is used alone, the only error introduced into the analysis by the process of clarification is caused by the volume of the precipitate of aluminum hydroxide. If only a few cubic centimeters are used, the volume of the dry solid is small and for all ordinary purposes negligible.

If the alumina cream contains an excess of alum and other soluble sulphates, its use is recommended by many as an aid to clarification by basic lead acetate in the analysis of very impure products where a large quantity of lead acetate is required. The alumina cream then fulfills several purposes. It precipitates the excess of lead as lead sulphate. It adds its own clarifying effect and tends to furnish a slightly acid solution, which decomposes some of the compounds which lead forms with some varieties of sugar, notably levulose.

Impure saccharine products usually contain large quantities of dissolved inorganic salts, so that the addition of a clarifier containing a relatively small quantity of soluble salts is not seriously detrimental.

The method of preparation described by the Association of Official Agricultural Chemists³⁷ is as follows: Prepare a cold saturated solution of alum in water and divide into two unequal portions. Add a slight excess of ammonium hydroxide to the larger portion and then add by degrees the remaining alum solution until a faintly acid reaction is secured.

(b) BASIC LEAD ACETATE

(1) **Preparation.**—Basic lead acetate is the clarifier of most extensive application. It is formed by chemical combination of normal lead acetate $\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2$ with litharge PbO . There are thought to be three well-defined basic acetates varying in the relative quantities of the two con-

³⁷ Bull. Bu. Chem., 107, p. 40.

stituents. These are $3 \text{ Pb } (\text{C}_2\text{H}_3\text{O}_2)_2 \cdot 2 \text{ PbO}$ the basic acetate containing the lowest percentage of combined litharge and the one ordinarily prescribed for clarification; $\text{Pb } (\text{C}_2\text{H}_3\text{O}_2)_2 \cdot \text{PbO}$ the monobasic acetate; and $\text{Pb } (\text{C}_2\text{H}_3\text{O}_2)_2 \cdot 2 \text{ PbO}$ the dibasic acetate. Basic lead acetate of a satisfactory degree of purity is prepared by some commercial firms, and it is in many cases advisable to use the purchased substance for preparing the clarifying solution. The laboratory method of preparation recommended by the Association of Official Agricultural Chemists³⁸ is as follows: Prepare lead subacetate solution by boiling 430 g of normal lead acetate, 130 g of litharge and 1000 cc of water for half an hour. Allow the mixture to cool and settle and dilute the supernatant liquid to 1.25 specific gravity with recently boiled water. Solid lead subacetate may be substituted for the normal salt and litharge in the preparation of the solution.

For some purposes a concentrated solution may be used, which is prepared as follows (Spencer's Handbook for Cane Sugar Manufacturing): Heat nearly to boiling for about half an hour 860 g of neutral lead acetate, 260 g of litharge, and 500 cc of water. Add water to compensate for the loss by evaporation. Cool, settle, and decant the clear solution. This solution may be prepared without heat, provided the mixture is set aside several hours, with frequent shaking.

With the exception of the basic acetate prepared by a few firms, the samples occurring in commerce and also samples prepared in the laboratory even by official methods vary in composition within wide limits. Basic acetates having the highest proportion of PbO have the greatest clarifying power, but also combine to the greatest extent the errors accompanying clarification with this reagent.

The constitution of basic acetate may be determined chemically by a double analysis of the sample.

(2) **Analysis.**—Weigh out 10 g of the solid or take a known volume of the solution containing approximately this quantity of the solid substance and dissolve in water in a 500-cc flask. In general this will give a milky solution, which is due to the partial hydrolysis of the lead salt. In order to avoid the possibility of the formation of basic lead sulphate subsequently, it is advisable to add a measured volume of normal acetic acid until a clear solution is obtained. Then add the equivalent of 60 cc of normal sulphuric acid, fill to a volume of 501.3 cc, close the flask, shake thoroughly, and allow the precipitate to settle. The extra 1.3 cc are to compensate for the volume of the precipitated lead sulphate. It may be added from a burette to the solution after filling to the 500 cc mark.

³⁸ Bull. Bu. Chem. 107, p. 40.

After the precipitate has settled determine the excess of sulphuric acid by adding to 100 cc of the clear solution a slight excess of BaCl_2 . Filter the precipitate, ignite, and weigh as BaSO_4 . The calculation of the total lead present computed as PbO is as follows:

$$5 \left[\text{cc } \text{H}_2\text{SO}_4 \times \text{normality factor} - \frac{\text{Wt. } \text{BaSO}_4}{\frac{1}{2} \text{ Mol. Wt. } \text{BaSO}_4} \right] \frac{1}{2} \text{ Mol. Wt. } \text{PbO}$$

$$\text{or } 5.578 \left[\text{cc } \text{H}_2\text{SO}_4 \times \text{factor} - \frac{\text{Wt. } \text{BaSO}_4}{.1167} \right]$$

To ascertain the quantity of lead present in the form of $\text{Pb} (\text{C}_2\text{H}_3\text{O}_2)_2$ and that in the form of PbO add to another 100 cc aliquot portion a few drops of phenolphthalein and titrate with a standard caustic alkali solution, taking the necessary precautions to free the solution from carbonic acid. The calculation of PbO is as follows:

$$5 \left[\text{Total cc normal acid added} - \text{cc normal alkali} \right] \frac{1}{2} \text{ Mol. Wt. } \text{PbO}$$

The total normal acid is the sum of the acetic and sulphuric. This computation gives the weight of lead present as PbO . If this is subtracted from the total PbO the remainder is the PbO present in the form of neutral acetate and this weight multiplied by the factor 1.4574 reduces it to the weight of neutral acetate.

The basic lead acetate has the great advantage of efficiency, but has also many disadvantages which require the exercise of great caution in its use. In general the minimum quantity which is necessary to clarify the solution should be used. This quantity is gauged by experienced workers with the requisite accuracy. The needed quantities for particular cases can not be stated, but the following approximate numbers are given as examples: For Java, Peruvian, and Cuban "first" sugars from 1 to 2 cc, molasses sugars 2 to 4 cc, Philippine III 3 to 6 cc. Molasses usually requires 6 to 12 cc. Many analysts follow up the lead by a little alumina cream. The washed alumina cream is used for high-grade samples, the cream with soluble sulphates for low-grade samples.

(3) **Corrections for the Volume of Precipitate.**—The basic lead acetate owes its clarifying action to its ability to precipitate the suspended albuminoids with other organic impurities. Since the total volume of 100 cc is occupied by the solution and precipitate the solution alone occupies somewhat less than the volume indicated and is thus correspondingly concentrated. The error in the polarization thus caused has occasioned considerable discussion and a number of methods have been devised either to correct or avoid it.

*Method of Sachs.*³⁹—This is practically a direct measurement of the volume of the precipitate. It is described in Spencer's Handbook, page 83, as follows: Clarify 100 cc of the juice or the dissolved normal weight with the subacetate as usual. Wash the precipitate by decantation first with cold water and finally with hot water until all of the sucrose is removed. Transfer the precipitate to a 100-cc flask and add one-half the normal weight of cane sugar (of known polarization), dissolve the sugar, and dilute the solution to 100 cc, mix, filter, and polarize, using a 400-mm observation tube.

The volume of the precipitate is $\frac{100 P' - 100 P}{P}$ in which P is the polarization of the sugar taken and P' the polarization of the sugar in presence of the precipitate.

*Method of Scheibler.*⁴⁰—To 100 cc of the sugar solution 10 cc of lead solution are added and the saccharimetric reading taken. A second solution is prepared by mixing the same volumes of the saccharine liquid and lead solution which is then diluted to 200 cc and polarized.

Scheibler's method may be expressed by the following equations: $r = \frac{100 R}{100 - A}$, where r is polariscopic reading, R is the true reading if the solution were contained in 100 cc and A is the volume of the precipitate.

Similarly $r_1 = \frac{100 R}{200 - A}$. Combining the two equations and eliminating A, we

obtain $R = \frac{r r_1}{r - r_1}$. A further simplification is due to C. A. Browne, who deduces the expression $R = 4 r_1 - r$.

Method of Horne.—The following method gives a more direct determination of this volume and is free from the difficulty of determining small differences between large numbers. A solution of the raw sugar is prepared and precipitated in the usual manner. The precipitate is allowed to settle and is washed by decantation, all the washings being poured through a weighed Gooch crucible. As little of the precipitate as possible is transferred to the filter. When the washing is completed the precipitate is transferred to a weighed pycnometer which is filled to the mark and weighed. The Gooch crucible is dried at 100° and weighed and the remainder of the precipitate poured on it. It is again dried and weighed. The difference between the first and final weighings gives the total weight of the lead precipitate.

³⁹ Revue Universelle de la Fabrication de Sucre, I, p. 451.

⁴⁰ Zs. f. Zuckerind. 1054; 1875.

The density of the precipitate is found in the following way:

Let c = Weight of precipitate transferred in decanting.

A = Weight of water in picnometer when filled.

B = Weight of water and precipitate in picnometer.

C = Weight of precipitate in picnometer found by difference between second and third weighing of Gooch crucible.

$C + W$ = total weight of precipitate.

$$\text{Density} = \frac{C}{A - (B - C)} \quad (20)$$

The total volume of the precipitate is then its total weight divided by its density.

$$\text{Volume} = \frac{W}{D} = \frac{C + c}{\frac{C}{A - (B - C)}} \quad (21)$$

If care is taken to avoid any considerable loss of precipitate during the decantation, the determination may be shortened by neglecting the small quantity of precipitate which is lost in this way. The washed precipitate may be transferred directly to the picnometer which is filled and weighed. The picnometer is then emptied directly upon a weighed Gooch filter. The volume of the precipitate is then the weight of water displaced in the picnometer by the precipitate or $A - (B - C)$. If the weight of the precipitate lost in the decantation does not exceed a few per cent the shorter method is satisfactory.

(4) **Horne's Dry Method.**—A method intended to avoid rather than correct for the effect of the volume of the lead precipitate has been proposed by Horne.⁴¹ Dissolve the sample in water and make up to 100 cc before adding the clarifier. Add a minimum quantity of dry basic lead acetate until sufficient clarification is obtained. Or, as in careful work with a lead solution, add the solid in successive small amounts until precipitation is almost complete. It is evident that it is necessary to stop short of complete precipitation because an excess of the solid which does not produce a corresponding precipitate serves to swell the volume of solution and a corresponding error is introduced.

Horne has been able to show that by this method the volume of the solution is very approximately that indicated.

(5) **Effect on Sucrose.**—It is often erroneously stated that basic lead acetate is without effect on the rotation of sucrose. The experiments of

⁴¹ J. Am. Chem. Soc., 26, p. 186.

Bates and Blake⁴² show that errors in rotation caused by excessive amounts of basic lead acetate are of equal importance to the other errors in saccharimetry. These authors have found, Fig. 9, that an excess of $\frac{1}{2}$ cc causes a diminution of polarization of 0.10° S; 1 cc, 0.12° S; 2 cc, 0.11° S; 3 cc, 0.09° S. The rotation reaches a minimum value when an excess of 1 cc is present. It returns to its initial value when 6 cc in excess have been added and continues to increase linearly with the amount of lead solution added until as much as 50 cc are present the rotation is increased by a whole degree Ventzke. This source of error is avoided if the minimum quantity of lead solution necessary to clarify is added.

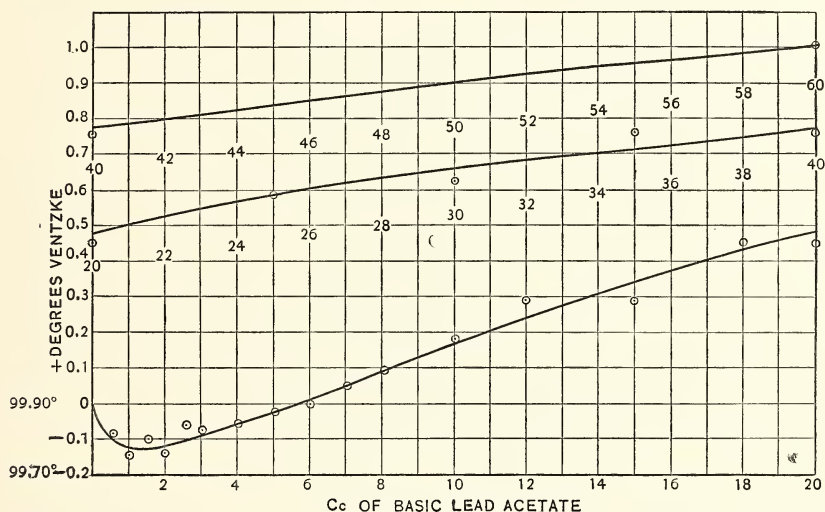


Fig. 9.—Influence of lead acetate on normal sugar solution

(6) **Effect on Levulose.**—By the action of basic lead acetate on levulose the direct polarization may be considerably disturbed. This effect may occur from two causes. A soluble combination of lead and levulose may be formed which has a lower specific rotation than levulose, or the lead-levulose compound may be actually precipitated from solution. The result in either case is an increase in dextro-rotation or a higher polarization. Prinsen Geerligs has shown that basic acetate of lead precipitates levulose when the same solution contains salts which are capable of producing insoluble compounds with lead.

The combinations between lead and levulose are very easily broken up by a slight acidification. Acetic acid is sufficiently effective, but many other acids have been used for this purpose. Sulphur dioxide, tannic acid,

⁴² Bull. B. S., 3, p. 105.

and as is frequently claimed a solution of alum is acid enough to decompose this rather loose combination. In any case only a slight excess of acid should be present.

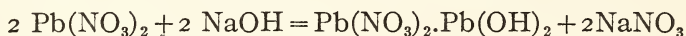
(c) BONE CHAR

In cases where the action of neither alumina cream nor lead subacetate is sufficient to produce a clear solution recourse may be had to bone black. Bone black for analytical purposes may be prepared by treating the granular material used in sugar refining with a slight excess of hydrochloric or nitric acid until all of the mineral matter is dissolved. The treated char is washed with boiling water, dried at 120°, and finely powdered and bottled. The more completely the material is freed from mineral matter the more effective is its action for analytical purposes. Bone black probably owes its clarifying action to the very large surface which is caused by its porosity.

The most serious error accompanying clarification with bone char is caused by its tendency to absorb sugar and thus give abnormally low readings. For this reason most official methods of clarification exclude bone black as an agent. It is difficult to make a correction for the amount of sugar absorbed, because it varies with the composition and concentration of the sample and the condition of the bone char. In order to avoid the error arising from the absorption of sugar, the absorption coefficient may be determined under the approximate conditions of the analysis or the solution may be made up to volume and filtered through a column of bone black, the first third of the filtrate being rejected.

(d) BASIC LEAD NITRATE (Herles's solution)

Herles's ⁴³ solution is prepared by dissolving 100 g of solid caustic soda in 2 liters of water and mixing with a solution of 1 kg of neutral lead nitrate in 2 liters of water. Under these conditions basic lead nitrate is precipitated.



The precipitate is washed free of soluble impurities and mixed to a cream for use in clarification. The clarification may also be performed by forming the basic lead nitrate in the solution to be polarized. This is done by first adding a measured quantity of the lead nitrate solution 1 to 10 cc, according to the darkness of the sample, and then an exactly equal quantity of the alkaline solution. The excess of alkali must be avoided. The whole is then shaken and made to volume. The latter procedure gives the better clarification, but introduces a considerable quantity of soluble salts, which may affect the polarization. The defects of the basic nitrate are in general

⁴³ Herles: Zs. Zuckerind Böhmen, 13, p. 559; 14, p. 343; 21, p. 189.

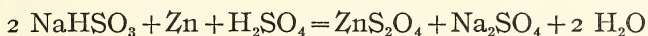
those of the basic acetate. The volume of the precipitate is even greater because of the bulk of the solid clarifier. The precipitation of reducing sugar is even more marked than in the case of the basic acetate.

(e) **HYPOCHLORITE (ZAMERON'S METHOD.)**

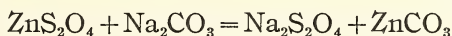
The hypochlorite solution is prepared by grinding 625 g of dry bleaching powder in a mortar with 1 liter of water. The mass is squeezed out in a sack and the extract filtered through paper. The filtered solution, about 700 to 800 cc of about 18° Bé, is preserved in a stoppered bottle of dark glass in darkness. To perform the clarification a few cubic centimeters of the hypochlorite solution are added to the sugar solution and then a few cubic centimeters of neutral lead acetate solution. The reagent usually causes a slight rise of temperature, so that the solution should be readjusted to the temperature of the polariscope before making to volume. This method of clarification is very effective; and if no great excess of the reagent is employed, the reducing sugars are unaffected. The volume of the precipitate which is increased because of insoluble lead chloride is the main fault of this method.

(f) **HYDROSULPHITE**

Sodium hydrosulphite is prepared by the reaction of zinc, sodium bisulphite, and sulphuric acid according to the formula



The zinc hydrosulphite is changed to the sodium compound by the reaction



The sodium hydrosulphite is salted out from solution by sodium chloride and dehydrated by warming with strong alcohol. The compound is then dried in a vacuum at 50°–60° C. This substance is produced commercially under the names of "Blankit" or "Redo" and is frequently used in the sugar manufacture for bleaching massecuites and in dissolved form as a wash for whitening sugar in the centrifugal machine. To prepare a solution for polarization a quantity of alumina cream is added and then a of the few crystals of hydrosulphite—0.1 g to 1 g, according to the color of the solution. The solution is made up to volume, shaken thoroughly, and filtered. As the solutions occasionally redarken they should be polarized immediately. The clarifying action according to Weisberg ⁴⁴ is due to free sulphurous acid and nascent hydrogen. The reduction by the latter leaves compounds which may be reoxydized and cause a redarkening of the solution.

⁴⁴ Centrbl. Zuckerind, 15, p. 975.

Another hydrosulphite derivative (sodium sulfoxylate-formaldehyde) known as "Rongalite" accomplishes a permanent clarification, but is slower and less effective than "Blankit."

The defects of hydrosulphites as clarifiers are in addition to the frequent redarkening, their effect on reducing sugars, the possible separation of finely divided sulphur, and their ineffectiveness in discharging the color of caramel bodies. Bryan⁴⁵ states that the rotation of dextrose is lowered by hydrosulphites and finds evidence of the formation of a lævo oxysulphonate. No immediate effect is observable upon sucrose or fructose, but sucrose is apparently inverted by a prolonged action. These clarifiers have not come into general use in analytical work, but nevertheless they are almost alone in the respect that they produce no volume error.

7. DETERMINATION OF MOISTURE

(a) GENERAL

An accurate determination of moisture in sugar products is a matter of great difficulty and the proper procedure for its estimation has not been definitely established. The water content of moist raw sugar or sugar products frequently exists in the state of a dense syrup and resists drying with great obstinacy. Sometimes also the material is very hygroscopic. At ordinary pressures moisture can only be removed by a prolonged heating at a high temperature. But a high temperature frequently exerts a destructive effect on the solid sugars. The destructive action of a temperature of 100° C is particularly important in the case of levulose and to a less extent in the cases of dextrose and sucrose. The best drying methods are those which combine high temperature and high vacuum. If the substance is in the form of a syrup, the drying is facilitated by mixing thoroughly with dry quartz sand or pumice. The action of the sand is to cause a larger area to be exposed and prevent the formation of a crust. Flaked asbestos, or for fluid substances a roll of filter paper, may be used.

Below are given various methods of determining dry substance, which are in common use. The method to be adopted depends somewhat upon the material. If levulose is present in considerable quantity, the temperature should not be raised over 70° C.

(b) METHOD OF THE UNITED STATES TREASURY

ARTICLE 1007. For the determination of moisture in sugars dry approximately 4 g in a nickel dish of a diameter of 55 mm and a height of 15 mm. Each sample shall be subjected to a temperature of 98° C for two hours.

⁴⁵ Bull. Bur. Chem., 116.

For the determination of moisture in molasses, syrups, and massecuites, dry, approximately 2 g in a flat dish of not less than 70 mm in diameter. Each sample shall be subjected to a temperature of 98° C for a period of two hours. Care must be taken to run the liquid in a film over the bottom of the dish and to retain in a horizontal position during the entire operation.

Although this method is capable of yielding uniform results, it is doubtful whether the last portions of moisture are removed, especially in the case of sirups.

(c) METHODS OF THE ASSOCIATION OF OFFICIAL AGRICULTURAL CHEMISTS⁴⁵

(1) **By Drying**—*Sugars*—*Official*.—Dry from 2 to 5 g in a flat dish (nickel, platinum, or aluminum) at the temperature of boiling water for 10 hours; cool in a desiccator and weigh; return to the oven and dry for an hour or until there is only a slight change in weight.

In Massecuites, Molasses, Honeys, and Other Liquid and Semiliquid Products—*Provisional*.—Prepare pumice stone in two grades of fineness. One of those should pass through a 1 mm sieve, while the other should be composed of particles too large for a millimeter sieve, but sufficiently small to pass through a sieve having meshes 6 mm in diameter. Make the determination in flat metallic dishes or in shallow, flat-bottom weighing bottles. Place a layer of the fine pumice stone 3 mm in thickness over the bottom of the dish, and upon this place a layer of the coarse pumice stone from 6 to 10 mm in thickness. Dry the dish thus prepared and weigh. Dilute the sample with a weighed portion of water in such manner that the diluted material shall contain from 20 to 30 per cent of dry matter. Weigh into the dish, prepared as described above, such a quantity of the diluted sample as will yield 1 g of dry matter. Use a weighing bottle provided with a cork through which a pipette passes if this weighing can not be made with extreme rapidity. Place the dish in a water oven and dry to constant weight at the temperature of boiling water, making trial weighings at intervals of two hours. In case of materials containing much levulose or other readily decomposable substances conduct the drying in vacuo at about 70° C.

Molasses with Quartz Sand—*Provisional*.—In a flat-bottom dish place 6 or 7 g of pure quartz sand and a short stirring rod. Dry thoroughly, cool in a desiccator, and weigh. Then add 3 or 4 g of the molasses, mix with the sand, and dry at the temperature of boiling water from 8 to 10 hours. Stir at intervals of an hour, then cool in a desiccator, and weigh. Stir,

⁴⁵ Bull. Bu. Chem., 107, p. 64.

heat again in the water oven for an hour, cool, and weigh. Repeat heating and weighing until loss of water in one hour is not greater than 3 mg.

Before using, digest the pure quartz sand with strong hydrochloric acid, wash, dry, ignite, and keep in a stoppered bottle.

(2) **Areometric Method** ⁴⁶—**Official**—*Specific Gravity, Water, and Total Solids by Means of a Spindle*.—The density of juices, sirups, etc., is most conveniently determined by means of the Baumé or Brix hydrometer, preferably the latter, as the graduation of the scale gives close approximations to the percentages of total solids. The Brix spindle should be graduated to tenths. The range of degrees recorded by each individual spindle should be as limited as possible. The solution should be as nearly as practicable of the same temperature as the air at the time of reading, and if the variation from the temperature of the graduation of the spindle amounts to more than 1°, a compensation must be applied according to the table of corrections for temperature, page 118. Before taking the density of a juice it should be allowed to stand in the cylinder until all air bubbles have escaped.

In case the sample is too dense to determine the density directly, dilute a weighed portion with a weighed quantity of water, or dissolve a weighed portion and dilute to a known volume with water. In the first instance the per cent of total solids is calculated by the following formula:

$$\text{Per cent of solids in the undiluted material} = \frac{WS}{W}$$

S = per cent of solids in the diluted material.

W = weight of the diluted material.

w = weight of the sample taken for dilution.

When the dilution is made to a definite volume, the following formula is to be used:

$$\text{Per cent of solids in the undiluted material} = \frac{VDS}{W}$$

V = volume of the diluted solution.

D = specific gravity of the diluted solution.

S = per cent of solids in the diluted solution.

W = weight of the sample taken for dilution.

A table for the comparison of specific gravities $\frac{17.5^\circ}{17.5^\circ}$, degrees Brix (per cent by weight of sucrose), and degrees Baumé, is given below.

⁴⁶ This method does not apply to low-grade sugar products, since materials high in salts give excessive percentages.

Specific Gravity, Water, and Total Solids by Means of a Picnometer.—

When a more accurate determination of the per cent of solids, or of water, or of the specific gravity is desired, the determination should be made with a specific gravity bottle or picnometer. When of too high density for a direct determination, the sample may be diluted, as described under (I).

When the number expressing the specific gravity found by analysis falls between the numbers given in the above table, the exact equivalent in degrees Brix or Baumé is found by a simple calculation.

Example: The picnometer shows the specific gravity of a certain sirup to be 1.20909. The table shows that the corresponding degree Brix is between 45.0 and 46.0. Subtracting the specific gravity of a solution of 45° Brix from the corresponding figure for 46°, we have (expressing the specific gravities as whole numbers) $121100 - 120565 = 535$, the difference in specific gravity for 1° Brix at this point in the table. Subtracting the specific gravity corresponding to 45° from the specific gravity found by analysis, we have $120909 - 120565 = 344$; $\frac{344}{535} = 0.64$, the fraction of 1° Brix more than 45°. The degree Brix, corresponding to a specific gravity of 1.20909, is therefore 45.64.

If the spindle reading or picnometer determination be made at any other temperature than 17.5°C., the result should be corrected by the use of Table 11, page 118.

Example: A sugar solution shows a reading of 30.2° Brix at 30° C. To find the necessary correction for the conversion of this reading to the reading which would have been obtained if the observation had been made at 17.5°C., find the vertical column in the table headed 30° Brix, which is the nearest to the observed reading. Follow down this column until the number is reached which is opposite to the temperature of observation, in this case 30°. The number found, 0.92, is to be added to the observed reading.

8. REFRACTOMETRIC ESTIMATION OF SOLIDS

The refractive index of sugar solutions and of sugar-house products has been found to be a reliable indication of the quantity of total solids present. Tolman and Smith found that solutions of practically all sugars in equal percentage composition by weight gave the same refractive indices. A determination of the index therefore serves as a measure of the dry substance contained in solution, even if it be a mixture of several different sugars. To extend the usefulness of the refractometer Geerligs showed that the refractive index of impure sugar solutions, even when the impurities

consisted of mineral salts was a reliable measure of total solid substance, and much superior to the analysis by density measurements.

(a) **ABBE REFRACTOMETER**

The refractometer of Abbe is especially adapted for solutions, sirups, and other saccharine liquids. In this instrument advantage is taken of the law of total reflection when the angle of incidence exceeds a certain value. The essential parts are a compensator and two flint glass prisms of index $N_D = 1.75$, one of which is cemented to a hinged mounting. The prisms are separated and a few drops of the liquid whose index of refraction is to be measured are placed upon the polished face of the fixed prism. The prisms are then slowly brought together again and the instrument swung into an upright position. The illumination is preferably obtained from an electric lamp or Welsbach gas mantle, although ordinary daylight will answer under certain conditions. The telescope is attached to a sector and the prisms to a movable arm. To set the instrument, the arm is adjusted until the intersection of the reticule in the telescope cuts the dividing line between the bright and dark portions of the field. The refractive index can then be read directly from the scale on the sector. Owing to the fact that the index of the liquid must always be less than that of the prisms in order to secure total reflection, indices may not be determined that are higher than 1.75, the index of the prisms.

In order to eliminate the dispersion produced by the prisms, a compensator consisting of two similar direct-vision prisms is placed in the telescope tube. By rotating one of these with respect to the other the exact compensation necessary to remove all color from the field is secured.

Since the refractive index of sugar solutions varies with the temperature, increasing as the temperature decreases, it is desirable to maintain uniform conditions during the measurement. To accomplish this, the prisms with the solution between them are surrounded by a water jacket.

(b) **IMMERSION REFRACTOMETER**

The immersion refractometer (described in *Z. angew. Chem.*, p. 1168, 1899) consists of a straight telescope tube with a prism of hard glass of index 1.51 attached rigidly to the lower end. This prism dips directly into the liquid whose refractive index is to be measured. The scale upon which the line of total reflection falls directly is divided into 110.0 arbitrary divisions comprising indices of refraction from 1.325 to 1.367. The reference point for calibration is scale division 15.0 which should be the reading for distilled water at 17.5°.

V. Stanek⁴⁷ describes a method for estimation of water in raw sugar by means of the immersion refractometer.

It is unfortunate that in the construction of his table Stanek has used the Mohr cubic centimeter as the unit of volume. According to his procedure 20 g of the sample are weighed out and transferred to a flask calibrated to contain 100 Mohr cc (the volume at 17.5° occupied by 100 g of pure water weighed in air with brass weights). The sugar is dissolved and made to volume and thoroughly shaken. It is then placed in a water bath to take up a steady temperature. The refractometer reading is made and simultaneously the temperature observed. The percentage of moisture is then read directly from the tables after the proper temperature correction is applied.

In case a flask calibrated to contain 100 Mohr cc is not at hand, a flask calibrated to contain 100 true cc may be used provided a weight of 19.954 g is taken and dissolved to make 100 true cc. (See Table 12.)

XII. POLARIMETRIC ANALYSIS OF OTHER SUGARS

1. SPECIFIC ROTATION

The specific rotation of any substance may be defined as the rotation caused by a length of 1 dm of a solution containing 1 g of substance in 1 cc. This value varies with the wave length of light used, it being greatest for the shortest wave lengths. It is, however, the common practice to express specific rotation in terms of the D lines of the sodium spectrum in spite of the doubtful advantage of such a light source. Specific rotation for sodium light is designated by the abbreviation $[\alpha]_D$ and is expressed mathematically in two ways:

$$[\alpha]_D = \frac{\alpha}{l \times c} \quad (22)$$

in which α expresses the observed rotation, l the length of the solution, and c the weight of substance in 1 cc.

Or

$$[\alpha]_D = \frac{\alpha}{l \times p \times d} \quad (23)$$

in which p = per cent concentration of substances and d the density of solution. Since $p \times d = c$ these two formulæ reduce to the same expression. $[\alpha]$ varies not only with the wave lengths of the light source, but also slightly with the concentration of substance and with temperature. It is therefore necessary to take these variations into consideration in order to apply the proper value of the specific rotation. Table 26, page 140, gives the values of

⁴⁷ Zs. Zuckerind Böhmen, 35, p. 57; 1910.

the specific rotations of the more important sugars at 5 per cent intervals of concentration. From this table the $[\alpha]_D$ for all other concentrations may be found by simple interpolation. Table 25, page 140, gives the formulas for variation of specific rotation from which the above tables were computed.

2. MONOCHROMATIC LIGHT METHOD

The methods described in the foregoing sections make it possible to apply a correct value for the specific rotation of the sugar in question for the particular temperature and concentration. This being known, it is merely necessary to observe the rotation of the solution and substitute the values in the equations $c = \frac{\alpha}{l \times [\alpha]_D}$ and $p = \frac{\alpha}{l d [\alpha]_D}$, where c is grams per 100 cc, α is the observed rotation, l is length of tube, p is number of grams in 100 g of solution, and d is the density of solution.

3. SACCHARIMETRIC METHOD

Since monochromatic light sources are always difficult to obtain, it is frequently more convenient to use a white light source and determine the sugar on a quartz wedge saccharimeter. The saccharimeter is particularly applicable to the sugar group because the rotary dispersions of quartz and the common sugars are very similar. The conditions for accurate observing are improved if the violet end of the spectrum is absorbed by the potassium bichromate cell. It must be remembered that the saccharimetric scale is defined by the rotation of sucrose, its hundred point being the rotation of 26 grams in 100 cc of solution. Therefore in order to determine a sugar having a different rotary power we must adjust the weight of the substance to the sucrose scale, i. e., the normal weight of the sugar in question is that weight dissolved in 100 cc of solution which will give a rotation of 100° on the sucrose scale. To compute this weight we should use, whenever the data are available, the results of direct determinations of the values of the rotations on the sucrose scale.

In the case of the first four sugars of the following table we have determinations of the relation between the rotation in sugar degrees and circular degrees of sodium light caused by the same solution. If this relation is known we can compute from the precisely known specific rotation the normal weight for the saccharimeter.

In the case of many sugars no direct determinations of the relative values of the sugar and circular degrees are available and in these instances the normal weight must be computed from the relative specific rotations of sucrose and of the sugar in question. This necessitates an assumption that

the rotation dispersion of all the sugars is the same as that of sucrose—which is not strictly true. These normal weights must therefore be considered only as the nearest approximation at present available. It is the purpose of this Bureau to obtain these data with the requisite precision. The computation depends upon the assumption that the normal weights of the sugars vary inversely as their specific rotations.

TABLE 20

Saccharimetric Normal Weights

Glucose	(1° V=,3448) hence $C = \frac{100 \times 34.48}{2 \times 53.46} = 32.248$
Lactose.....	(1° V=,3452) hence $C = \frac{100 \times 34.52}{2 \times 52.53} = 32.857$
Maltose	(1° V=,3449) hence $C = \frac{100 \times 34.49}{2 \times 138.25} = 12.474$
Raffinose (5 H ₂ O)	(1° V=,3450) hence $C = \frac{100 \times 34.50}{2 \times 104.5} = 16.507$
Inverse Ratio of Specific Rotations]	
Fructose	18.592
Invert sugar.....	86.450

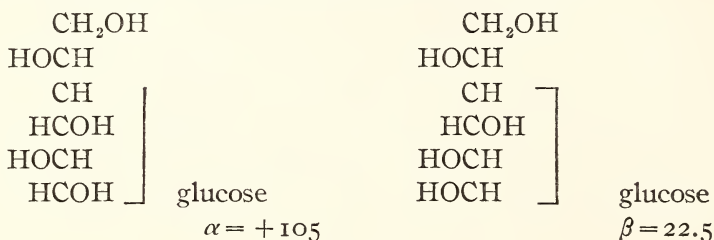
Thus in the determination of these sugars it is merely necessary to weigh out the appropriate normal weight of the sugar and proceed exactly as in the analysis of sucrose. The specific rotation in general is not precisely proportional to the concentration of the sugar and for exact work a correction should be applied for readings which vary much from the hundred degree point. Many experimenters advise using a variable normal weight according to the concentration of the sugar taken, but this requires a previous knowledge of the quantity of sugar present or a preliminary assay of the material. It is much more convenient to use a uniform normal weight and apply a correction for the various parts of the sugar scale. In Table 27 are given the corrections for dextrose at 10° intervals.

4. MUTAROTATION

In a very large class of sugars a considerable lapse of time is required for the dissolved sugar to exhibit a stable rotary power. The freshly prepared solution in general possesses a relatively high activity which steadily decreases according to the laws of unimolecular reactions to a steady state where no further change occurs. This phenomenon is called "mutarotation." The specific rotation of the sugar is expressed in terms of this equilibrium condition. Mutarotation has been satisfactorily explained by the discovery of two modifications of each of the sugars in which the phenomenon exists. These two modifications have been designated the α and β forms.

When the sugar crystallizes but one of these forms separates from solution, usually on account of a considerable difference in solubility, and, consequently, when a fresh solution is prepared the rotary power of this form is exhibited. The most plausible explanation of the isomerism of the α and β forms is connected with the end carbon atom which is capable of changing its relation to the rest of the molecule.

For example, in the case of dextrose the mutarotation reaction is regarded as a balanced reaction between the two forms



The steady state is, under this hypothesis, a state in which the reactions velocities $\alpha \rightarrow \beta$ and $\beta \rightarrow \alpha$ are equal.

In analytical work it is necessary that the solution of the substance reach its equilibrium before the rotation is recorded. This may be accomplished simply by allowing the solution to stand at room temperature until constant rotation is reached. This way is preferable whenever possible.

If it is desired to complete the reading speedily, equilibrium may be reached by heating the solution to a high temperature. It is reached almost instantly at 100° . The addition of 0.1 per cent ammonia or $\frac{N}{200}$ KOH will cause the completion of the reaction in 10 to 15 minutes. Stronger alkali will tend to cause decomposition.

XIII. ESTIMATION OF REDUCING SUBSTANCES

1. PREPARATION OF SOLUTIONS

(a) SOXHLET SOLUTION

- A. 34.639 g $\text{CuSO}_4 \cdot 5 \text{H}_2\text{O}$ in 500 cc of solution.
 - B. 173 g of Rochelle salts, 51.6 g NaOH in 500 cc of solution.
- For analysis mix equal volumes of A and B just before using.

(b) ALLIHN'S SOLUTION

- A. Dissolve 34.639 g $\text{CuSO}_4 \cdot 5 \text{H}_2\text{O}$ and dilute to 500 cc.
- B. Dissolve 173 g of Rochelle salts and 125 g of KOH and dilute to 500 cc.

2. PREPARATION OF CRUCIBLES

Prepare the asbestos,⁴⁸ which should be the amphibole variety, by first digesting with 1:3 hydrochloric acid for two or three days. Wash free from acid and digest for a similar period with soda solution, after which treat for a few hours with hot alkaline copper tartrate solution of the strength employed in sugar determinations. Then wash the asbestos free from alkali, finally digest with nitric acid for several hours, and after washing free from acid shake with water for use. In preparing the Gooch crucible load it with a film of asbestos one-fourth inch thick, wash this thoroughly with water to remove fine particles of asbestos; finally wash with alcohol and ether, dry for 30 minutes at 100° C, cool in a desiccator, and weigh. It is best to dissolve the copper precipitate with nitric acid each time after weighing and use the same felts over and over again, as they improve with use.

In order to prepare the Gooch-Munroe-Nebauer crucible, a quantity of ammonium chlor-platinate is made by dissolving scrap platinum in aqua regia. Boil off the excess of nitric acid by repeated additions of hydrochloric acid. Evaporate to dryness and dissolve in a small quantity of water. Precipitate the ammonium salt by adding ammonium chloride. The precipitate is collected on a filter and dried. To obtain larger crystals it may be recrystallized from hot water. To make the mat sprinkle a uniform layer of the ammonium chlor-platinate in the bottom of the Gooch crucible, preferably one with small holes. A small platinum foil should be placed under the crucible to prevent the salt from sifting through. Crucible and cap are then placed in a larger porcelain or platinum dish and heated gradually to decompose the ammonium salt. When decomposition is complete allow the crucible to cool. If on inspection an even unbroken layer of platinum sponge is obtained it should be very carefully pressed down with a glass rod, the end of which has been flattened to a smooth area 5–10 mm in diameter. The spongy platinum is pressed down gently at first, later more and more firmly, and is finally burnished slightly. The operation is by no means an easy one, and is far more difficult in a porcelain crucible than in a platinum one, but after several attempts the necessary experience is obtained. These crucibles have the advantage of greater constancy of weight and in general, if correctly made, permit a more rapid and more perfect filtration. Furthermore, the mat is not deranged by any of the ordinary manipulations.

3. UNIFIED METHOD OF MUNSON AND WALKER⁴⁸

(See Fee Schedule 45)

Transfer 25 cc each of solutions A and B of the Soxhlet reagent to a 400 cc Jena or Non-sol beaker and add 50 cc of reducing sugar solution, or

⁴⁸ J. Amer. Chem. Soc., 28, p. 663; 29, p. 541.

if a smaller volume of sugar solution be used, add water to make the final volume 100 cc. Heat the beaker upon an asbestos gauze over a Bunsen burner, so regulate the flame that boiling begins in four minutes, and continue the boiling for exactly two minutes. Keep the beaker covered with a watch glass throughout the entire time of heating. Without diluting, filter the cuprous oxide at once on a Gooch crucible, using suction. Wash the cuprous oxide thoroughly with water at a temperature of about 60° C then with 10 cc of alcohol and finally with 10 cc of ether. Dry for 30 minutes in a water oven at 100° C, cool in a desiccator, and weigh as cuprous oxide, or determine the copper by one of the methods given on pages 75-78.

The analytical procedure for any one of these sugars may be verified by carrying out the operation upon the standard dextrose sample or upon the invert sugar solution.

A table by Munson and Walker has been computed for the determination of reducing sugar in the presence of sucrose under conditions where a large quantity of reducing substance is present, and where a small quantity is present. If the composition of the mixture is known approximately the weight of substance required can be judged without a previous assay. If less than 10 per cent of reducing sugar is present a weight of 2 g of total sugar should be taken in 50 cc. If more than 10 per cent, 0.4 g in 50 cc is the required amount. For unknown mixtures it is best to make an analysis with either one of the amounts of total sugar. This will serve either as a preliminary or final assay according to the amount present. The method allows great latitude of procedure.

4. HERZFELD'S METHOD ⁴⁹ FOR LOW PERCENTAGES OF REDUCING SUGAR

(See Fee Schedule 45)

Herzfeld's method is intended for high grades of raw sugar containing less than 1.5 per cent of reducing substances. Clarification is performed with normal lead acetate in order not to precipitate reducing sugar. It is convenient to take 44 g of sugar in a 200-cc flask, dissolve in about 100 cc, add normal lead acetate just sufficient to clarify, complete to 200 cc and filter. One hundred cubic centimeters of the filtrate is taken in a 100 to 110-cc flask and sufficient sodium carbonate or sulphate added to precipitate the excess of lead. The volume is completed to 110 cc, the solution shaken and filtered; 50 cc of the filtrate contains 10 g of the sugar.

To perform the analysis, take 25 cc each of A and B of Soxhlet's solution, heat to boiling, and add 50 cc of the clarified solution. Bring the mix-

⁴⁹ Zs. Ver. Zuckerind, p. 985, 1885.

ture to boiling and boil for exactly two minutes. The cuprous oxide is filtered off, washed, and the copper determined. If the sugar contains more than 1.5 per cent of reducing sugar the method of Munson and Walker must be employed.

5. ALLIHN'S METHOD FOR GLUCOSE⁵⁰

(See Fee Schedule 45)

ALLIHN'S SOLUTIONS

(a) **Copper Sulphate Solution.**—Dissolve 34.639 g of $\text{CuSO}_4 \cdot 5 \text{H}_2\text{O}$ in water and dilute to 500 cc.

(b) **Alkaline Tartrate Solution.**—Dissolve 173 g of Rochelle salts and 125 g of potassium hydroxide in water and dilute to 500 cc.

Place 30 cc of the copper solution, 30 cc of the alkaline-tartrate solution, and 60 cc of water in a beaker, and heat to boiling. Add 25 cc of the solution of the material to be examined, which must be so prepared as not to contain more than 0.250 g of glucose, and boil for exactly two minutes, keeping the beaker covered. Filter immediately through asbestos without diluting and obtain the weight of copper by one of the methods, pages 75–78. The corresponding weight of dextrose is found from Table 23, page 138, prepared by Allihn.

6. ESTIMATION OF COPPER IN THE CUPROUS OXIDE PRECIPITATE

The estimation of copper in the cuprous oxide precipitate may be accomplished gravimetrically or volumetrically. The gravimetric methods, which consist of the weighing of this precipitate either directly or after conversion into copper or cupric oxide, may be employed only in case the precipitate is uncontaminated. Contamination may be caused by the precipitation of inorganic or organic impurities during the reduction. Such precipitation is the more likely to occur, the cruder the sample to be analyzed. In case a contaminated precipitate is suspected, the copper in the precipitate must be determined analytically.

The electrolytic method is available for impure precipitates. The volumetric determination by use of KMnO_4 is reliable if the precipitate is not contaminated by organic substances. Most generally applicable for accurate work are the electrolytic methods and the iodimetric methods of Low and Kendall. It is the intention of this Bureau to study these various methods critically.

Of the following methods sections a, b, d, e, and f have been adopted by the Association of Official Agricultural Chemists.⁵¹

⁵⁰ Bull. Bur. Chem., 107, p. 49.

⁵¹ Bull. Bur. Chem., 107, p. 51.

(a) REDUCTION IN HYDROGEN

“Filter the cuprous oxide immediately through a weighed filtering tube made of hard glass, using suction. Support the asbestos film in the filtering tube with a perforated disk or cone of platinum, and wash free from loose fibers before weighing; moisten previous to the filtration. Provide the tube with a detachable funnel during the filtration, so that none of the precipitate accumulates near the top, where it could be removed by the cork used during the reduction of the cuprous oxide. Transfer all the precipitate to the filter and thoroughly wash with hot water, following the water by alcohol and ether successively. After being dried, connect the tube with an apparatus for supplying a continuous current of dry hydrogen, gently heat until the cuprous oxide is completely reduced to the metallic state, cool in the current of hydrogen, and weigh. If preferred, a Gooch crucible may be used for the filtration.

(b) DIRECT WEIGHING OF CUPROUS OXIDE

“Prepare a Gooch crucible with an asbestos felt $\frac{1}{4}$ of an inch thick. First thoroughly wash the asbestos with water to remove small particles, then follow successively with 10 cc of alcohol and 10 cc of ether, and dry the crucible and contents 30 minutes in a water oven at the temperature of boiling water.

“Collect the precipitated cuprous oxide on the felt as usual, thoroughly wash with hot water, then with 10 cc of alcohol, and finally with 10 cc of ether. Dry the precipitate 30 minutes in a water oven at the temperature of boiling water; cool and weigh. The weight of cuprous oxide multiplied by 0.8883 gives the weight of metallic copper.”

(c) DETERMINATION OF COPPER AS CUPRIC OXIDE

The cuprous oxide is ignited (best in a muffle) at red heat for 15 to 20 minutes in an oxidizing atmosphere. The weighing should be performed rapidly to prevent increase of weight due to absorption of moisture. Multiply by 0.7989 to convert to copper.

(d) ELECTROLYTIC DEPOSITION FROM NITRIC ACID SOLUTION

“Filter and wash as under (e). Transfer the asbestos film and adhering oxide to the beaker. Dissolve the oxide still remaining in the crucible by means of 2 cc of nitric acid (specific gravity, 1.42), adding it with a pipette and receiving the solution in the beaker containing the asbestos film. Rinse the crucible with a jet of water, allow the rinsings to flow into the beaker. Heat the contents of the beaker until the copper is all in solution, filter, dilute the filtrate to a volume of 100 cc or more, and electrolyze. When a

nitrate solution is electrolyzed, the first washing of the deposit should be made with water acidulated with sulphuric acid, in order that the nitric acid may be all removed before the current is interrupted.

(e) VOLUMETRIC PERMANGANATE METHOD

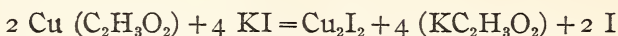
"Filter the cuprous oxide in a Gooch, wash the beaker and precipitate thoroughly with hot water without any effort to transfer the precipitate to the filter. Transfer the asbestos film to the beaker, add about 30 cc of hot water, and heat the precipitate and asbestos thoroughly. Rinse the crucible with 50 cc of a hot saturated solution of ferric sulphate in 20 per cent sulphuric acid, receiving the rinsings in the beaker containing the precipitate. After the cuprous oxide is dissolved, wash the solution into a large Erlenmeyer flask and immediately titrate with a standard solution of potassium permanganate. One cubic centimeter of the permanganate solution should equal 0.010 g of copper. In order to determine the strength of this solution, make six or more determinations with the same sugar solution, titrating one-half of the precipitate obtained, and determining the copper in the others by electrolysis. The average weight of copper obtained by electrolysis, divided by the average number of cubic centimeters of permanganate solution required for the titration, is equal to the weight of copper equivalent to 1 cc of the standard permanganate solution. A solution standardized with iron or oxalic acid will give too low results."

(f) LOW'S VOLUMETRIC IODIDE METHOD ⁶²

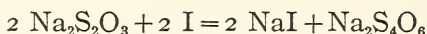
(1) **Standardization of the Thiosulphate Solution.**—Prepare a solution of sodium thiosulphate containing about 19 g of the pure crystals to the liter. Standardize as follows: Weigh accurately about 0.2 g of pure copper foil and place in flask of about 250 cc capacity. Dissolve by warming with 5 cc of a mixture of equal volumes of strong nitric acid (sp. gr. 1.42) and water and then dilute to about 50 cc. Boil for a few minutes to expel partially the red fumes and then add 5 cc of strong bromine water and boil until the bromine is thoroughly expelled. The bromine is to insure the complete destruction or removal of the red fumes. Remove from the heat and add a slight excess of strong ammonia water. Ordinarily it suffices to add 7 cc of ammonia water of 0.90 sp. gr. Again boil until the excess of ammonia is expelled, as shown by a change of color of the liquid and a partial precipitation of the copper as hydroxide or oxide. Now add strong acetic acid in slight excess, perhaps 3 or 4 cc of the 80 per cent acid in all and again boil for a moment if necessary to redissolve the copper precipitate. Cool to room tempera-

⁶² J. Amer. Chem. Soc., 24, p. 1082, and Bull. Bur. Chem., 107, p. 241.

ture and add about 3 g of potassium iodide, or 6 cc of a solution of the salt containing 50 g in 100 cc. Cuprous iodide will be precipitated and iodine liberated according to the reaction.



The free iodine colors the mixture brown. Titrate at once with the thiosulphate solution until the brown tinge has become weak and then add sufficient starch liquor to produce a marked blue coloration. Continue the titration cautiously until the color due to free iodine has entirely vanished. The blue color changes toward the end to a faint lilac. If at this point the thiosulphate be added drop by drop and a little time be allowed for complete reaction after each addition, there is no difficulty in determining the end point within a single drop. One cubic centimeter of the thiosulphate solution will be found to correspond to about 0.005 g of copper. The reaction between the thiosulphate and the iodine is:



The starch liquor may be made by boiling about 0.5 g of starch with a little water and diluting with hot water to about 250 cc. The liquor should be homogeneous and free from lumps. It should be used cold and must be prepared frequently.

(2) **Analysis.**—After washing the precipitated cuprous oxide, cover the Gooch crucible with a watch glass and dissolve the oxide by means of 5 cc of warm nitric acid (1:1) poured under the watch glass with a pipette. Catch the filtrate in a flask of 250 cc capacity and wash watch glass and Gooch crucible free of copper; 50 cc of water will be sufficient. Boil to expel red fumes, add 5 cc of bromine water, boil off the bromine, and proceed as in standardizing the thiosulphate.

(g) **KENDALL'S MODIFIED IODIDE METHOD** ⁶³

The cuprous oxide, after filtering and washing upon a Gooch crucible, is dissolved in 10 to 15 cc of 30 per cent nitric acid in a 300 cc Erlenmeyer flask. The volume of the solution should now be 50 to 60 cc and of acidity equivalent to 4 to 5 cc of concentrated nitric acid. A greater volume or acidity should be avoided. The temperature should not be above 25°. Five cubic centimeters of the hypochlorite solution are now added and the flask well shaken. A sufficiency of hypochlorite solution is indicated by a change from blue to greenish tint or by liberation of chlorine. The solution is allowed to stand about two minutes. Ten cubic centimeters of 5 per cent colorless phenol solution are now added as quickly as possible. The

⁶³ J. Amer. Chem. Soc., 33, p. 1947.

chlorine gas above the solution is removed by blowing into the flask and the sides are rinsed down. The solution is now made alkaline with sodium hydroxide until a slight precipitation occurs. Acidify with a few drops of acetic acid. Add 10 cc of 30 per cent potassium iodide solution and titrate with thiosulphate.

The sodium hypochlorite solution is prepared by boiling 112 g of calcium hypochlorite and 100 g of anhydrous sodium carbonate in 1200 cc of water. Five cubic centimeters of the filtered solution are added to 100 cc of water containing 5 cc of 30 per cent KI solution and a few cubic centimeters of dilute HCl solution, and a few cubic centimeters of dilute HCl added. The liberated iodine is titrated with 0.1 N sodium thiosulphate. The volume of the solution, is now adjusted so that 5 cc of the hypochlorite solution are equivalent to 30 cc of 0.1 N sodium thiosulphate.

Additional methods are the electrolytic methods in which sulphuric acid is present⁵⁴ and the thiocyanate method of Volhard and Pflüger.⁵⁵

7. VOLUMETRIC DETERMINATION OF REDUCING SUGAR⁵⁶

(a) SOXHLET'S METHOD

"Make a preliminary titration to determine the approximate percentage of reducing sugar in the material under examination. Prepare a solution which contains approximately 1 per cent of reducing sugar. Place in a beaker 100 cc of the mixed copper reagent and approximately the amount of the sugar solution for its complete reduction. Boil for two minutes. Filter through a folded filter and test a portion of the filtrate for copper by use of acetic acid and potassium ferrocyanide. Repeat the test, varying the volume of sugar solution, until two successive amounts are found which differ by 0.1 cc, one giving complete reduction and the other leaving a small amount of copper in solution. The mean of these two readings is taken as the volume of the solution required for the complete precipitation of 100 cc of the copper reagent. Under these conditions 100 cc of the mixed copper reagent require 0.475 g of anhydrous dextrose or 0.494 g of invert sugar for complete reduction. Calculate the percentage by the following formula:

V = the volume of the sugar solution required for the complete reduction of 100 cc of the copper reagent.

W = the weight of the sample in 1 cc of the sugar solution.

$$\text{Then } \frac{10 \times 0.475}{VW} = \text{per cent of dextrose} \quad (24)$$

$$\text{and } \frac{100 \times 0.494}{VW} = \text{per cent of invert sugar.} \quad (25)$$

⁵⁴ Bull. Bur. Chem., 107, p. 52.

⁵⁵ Pflüger's Archiv., 69, p. 423.

⁵⁶ Bull. Bur. Chem., 107, p. 42.

(b) STANDARD MATERIALS FOR CHECKING

The volumetric determination should be checked frequently against known solutions of pure dextrose or of pure invert sugar as the volume of solution reduced varies with the details of manipulation. The Bureau of Standards offers standard samples of pure sucrose and dextrose for this purpose.⁵⁷ The former may be used to prepare invert sugar solutions or to make up sucrose-invert sugar mixtures.

8. RATIO OF REDUCING POWERS OF REDUCING SUGARS

The term "reducing power" signifies the weight of copper reduced by a given weight of sugar which may, if desired, be taken as unit weight. The usual method of expressing reducing power is not, however, in terms of copper, but in terms of the relative weights of two sugars required to produce the same weight of copper. One of these sugars, namely, dextrose, is arbitrarily selected to serve as a standard reducing substance and its reducing power is said to be 1. The ratio of the weight of dextrose to that of the sugar in question is said to be the reducing ratio or reducing factor. These ratios have been determined by C. A. Browne⁵⁸ and are given in the appended table. In order to reproduce these ratios, quantities of sugar in excess of 50 mg are required and Allihn's solution and method should be employed. If any sugar other than dextrose be analyzed in this way and determined as dextrose its actual weight is $\frac{1}{\text{factor}}$ times the weight of dextrose as given in Allihn's table. The reducing ratio is of great importance in the analysis of sugar mixtures. Suppose for example we have determined a mixture of two sugars and have expressed the result as per cent dextrose = R . The respective percentages of the two sugars are given by x and y in the expression

$$ax + by = R \quad (26)$$

where a and b are the reducing factors. The factors for the various sugars are given in Table 24.

TABLE 24

Reducing Power Factors by Allihn's Method

Dextrose.....	1.000	Arabinose.....	1.032
Invert sugar.....	.958	Xylose.....	.983
Levulose.....	.915	Lactose.....	.66-.71
Galactose.....	.898	Maltose.....	.56-.62

⁵⁷ See p. 81 of this circular.⁵⁸ J. Amer. Chem. Soc., 28, p. 439.

XIV. PREPARATION OF PURE SUGARS

1. DEXTROSE

(See Fee Schedule 13)

With a view to assisting in the unification of analytical sugar work this Bureau issues as one of its standard samples chemically purified dextrose. In the preparation of this material the purest "anhydrous glucose" of commerce containing at least 90 per cent dextrose is submitted to a preliminary treatment similar to that described by Bauer.⁵⁹ The crude material is digested in a shaking machine with alcohol in order to wash the mother liquor from the crystals. The mass is then poured into a centrifugal machine and drained at high velocity. The drained crystals are then washed repeatedly with fresh portions of alcohol after each addition, running the machine at 3000 r. p. m. The washed substance is dissolved by heating in 40 per cent of its weight of water and 140 cc of alcohol added for each 100 g of the washed substance. This mixture is then heated on a steam bath and filtered to remove the precipitated impurities. The filtrate is boiled in the vacuum boiling apparatus described on page 84 to about 60 per cent sugar. The supersaturated liquid is then transferred to a shaking machine, a few crystals of dextrose added, and the substance allowed to crystallize in motion. After standing over night the crystal mass is centrifuged and washed four or five times with redistilled alcohol. The crystals obtained are very white and possess already a high purity. They are then dissolved in water, the solution filtered through asbestos into the boiling apparatus and recrystallized. The second crystals are carefully dried and analyzed for moisture, ash, polarization, and reducing power. If these tests indicate the presence of any remaining impurity the recrystallization is repeated until a satisfactory product is obtained.

The standard dextrose sample may be used to standardize analytical determinations of reducing substances. Frequently it may replace the usual invert sugar solution and has the advantages of greater convenience in the preparation of the solution and greater certainty of composition. Some uncertainty arises in the preparation of invert sugar solutions owing to the question of purity of the sucrose and the method of inversion employed. Reversion products may be formed or either levulose or dextrose injured by too long action of the acid. Furthermore, if the solution is preserved, decomposition may occur if either acid or alkali is in excess. The standard

⁵⁹ Orig. Comm. 8 Int. Congress of App. vol. 13, p. 21.

dextrose solution may be prepared very readily and conveniently by weighing out the required amount of solid substance and dissolving in the necessary volume of water. In this way a neutral solution of known composition is very rapidly and conveniently prepared.

Instead of the dextrose solution a solution of invert sugar may be used if carefully prepared.

2. STANDARD INVERT SUGAR SOLUTION

[Method of the Association of Official Agricultural Chemists]

"Dissolve 4.75 g of pure sucrose in 75 cc of water, add 5 cc of 38.8 per cent hydrochloric acid and set aside during a period of 24 hours at a temperature not below 20° C; or if the temperature be above 25° C set aside for 10 hours. Neutralize the acid exactly with dilute sodium hydroxide and make up to 1 liter; 100 cc of this solution contains 500 mgms of invert sugar."

The practice of checking frequently the analytical work on reducing substance determination should be observed whether a volumetric or gravimetric method is employed. The amount of reduced copper obtained is dependent in great measure upon the conditions of the particular analysis carried out. Errors may arise from impurities in reagents, time of boiling, or from many other circumstances connected with individual differences of procedure, but these are all eliminated if the analyst standardizes his own procedure by means of a known quantity of reducing substance and subsequently adheres rigidly to that same procedure.

3. SUCROSE

(See Fee Schedule 13)

Most of the methods for the purification of sucrose which have been described depend upon the use of alcohol as a precipitant. Sucrose is almost insoluble in absolute alcohol and its solubility in alcohol-water mixtures diminishes very rapidly as the concentration of alcohol increases.

(a) METHOD OF HERZFELD ⁶⁰

Prepare a cold, saturated, filtered, refined sugar solution and with continual stirring add an equal volume of 96 per cent alcohol. Filter after 15 minutes, wash with ether, and dry it in a water bath.

(b) METHOD OF HERLES

This method gives particular attention to the elimination of raffinose. To exclude traces of raffinose, precipitate a cold, saturated, filtered solution

⁶⁰ v. Lippmann *Die Chem. der Zuckerarten*, II, 1051.

of refined sugar with alcohol, warm on a water bath to 60° , decant the solution, pour fresh alcohol on the precipitate, warm with stirring, decant again, wash the sugar on a filter with absolute alcohol, and dry in a thin layer on filter paper at 30° to 40° .

On account of the well-known solubility of raffinose in methyl alcohol many operators have used this as a precipitant to insure the removal of this impurity.

(c) METHOD OF THE INTERNATIONAL COMMITTEE

To prepare pure sugar, further purify the purest commercial sugar in the following manner: Prepare a hot, saturated, aqueous solution, precipitate the sugar with absolute ethyl alcohol, spin the sugar carefully in a small centrifugal machine, and wash in the latter with absolute alcohol. Redissolve the sugar thus obtained in water, again precipitate the saturated solution with alcohol, and wash as above. Dry the second crop of crystals between blotting paper and preserve in glass vessels for use. Determine the moisture still contained in the sugar and take this into account when weighing the sugar which is to be used.

(d) METHOD OF BATES AND JACKSON

A method of purification has been developed at this Bureau in which recrystallization from aqueous solution is utilized. The purest granulated sugar of commerce is dissolved in an equal weight of water. This relatively dilute solution is clarified from albumenoids and suspended material by the addition of alumina cream which has been carefully freed from soluble salts by continued washing and testing the wash water by barium chloride. The solution of sugar is filtered by pouring on large fluted filters of hardened filter paper. The filtered solution which usually has the brilliancy of distilled water is boiled in a vacuum-distilling apparatus at a temperature not exceeding 35° C until the concentration of the solution, which was initially 50 per cent, reaches 76 to 80 per cent.

The requisites for a serviceable concentrator may be briefly summarized as follows: 1, Cleanliness; 2, low boiling point; 3, large capacity; 4, filtration of entering sirup.

The concentrator is shown diagrammatically in Fig. 10. The entire assembly with the exception of the aluminum vessel B, and condensing coils C, is of glass and with the exception of the small asbestos filter the sirup never comes in contact with any other substance. The evacuating is done by a power-driven Duplex and Geryk pump connected at D. When it is desired to concentrate a sugar sirup the procedure is as follows: The

solution, usually 40 to 50 per cent concentration is placed in the flask A, and the entire system evacuated up to the cock E. This cock is then carefully opened and the solution slowly driven through the asbestos filter into the boiling flask F, capacity 13 liters. Here it is gently warmed by the water bath, and the temperature of the sirup noted on the thermometer G. In order to obtain any desired boiling point it is only necessary to regulate the pressure. The degree of the vacuum is indicated by the mercury gauges H, H. The efficiency of the assembly is such that sirup is rapidly brought to the desired concentration of about 80 per cent at a temperature below

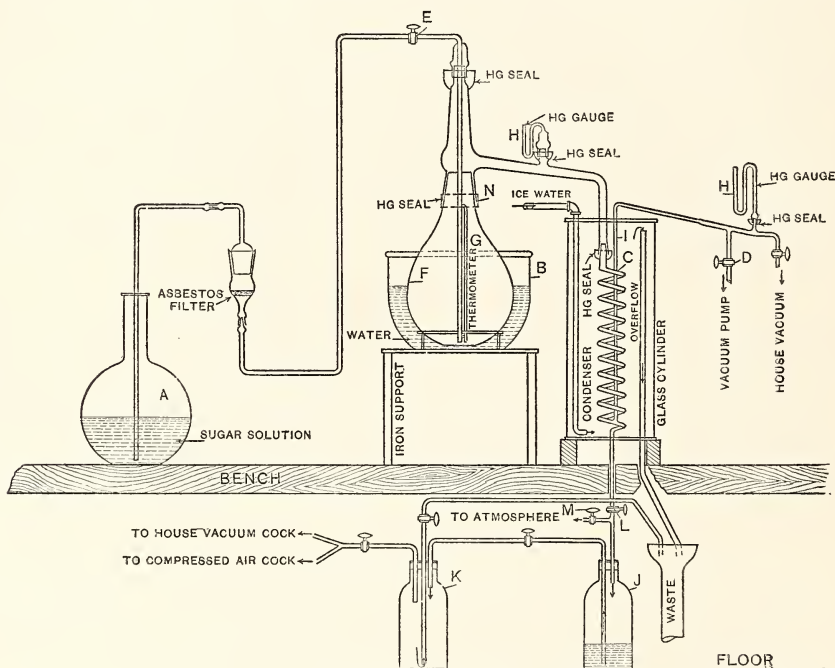


Fig. 10.—*Vacuum apparatus for concentrating sirups*

32° C. This is made possible by the high efficiency of the condensing system and by having all joints carefully ground to a fit. The stop cocks are lubricated with water or sugar sirup. The condensing coils C are of copper, eight in number, connected in parallel, and immersed in ice water. To prevent vapor reaching the vacuum pump, the pipe I is joined to the base of the condenser. As rapidly as the vapors condense they pass into the vessel J and subsequently by closing the cock L and opening M are expelled into K, from which the liquid is eventually driven into the waste. By noting the quantity of this liquid, the concentration of the sirup in F is known at all times.

The question of size of crystals is of the first importance. In general the smaller the crystals the less the "included solvent" or entrapped mother liquor. When the solution in the boiling flask F has reached the desired concentration, the vacuum is broken at N and the solution poured out to crystallize. Crystallization in general does not begin in these pure solutions until they are seeded with a few fine crystals of sugar. This is not done until after the solution is removed from the boiling flask. Two methods of crystallization have been tried. In the first the concentrated solution is transferred to a precipitation jar. It is then carefully stirred with a glass rod provided with a glass shield. This procedure gives satisfactory results so far as the control of the crystal growth is concerned, but it is laborious. In the second, the liquid is transferred to a crystallizer, a cross section of which is shown in Fig. 11. By this means it was found practicable to crystallize from a larger quantity of liquid, and with no danger of contamination. The device is very simple and consists of a hardwood box mounted on bearings and driven by an electric motor. The supports A, A, which carry the container are adjustable in order to keep the center of gravity on the axis of rotation. The box is rotated at about 35 revolutions per minute, so that the contents are subjected to a gentle and continuous agitation.

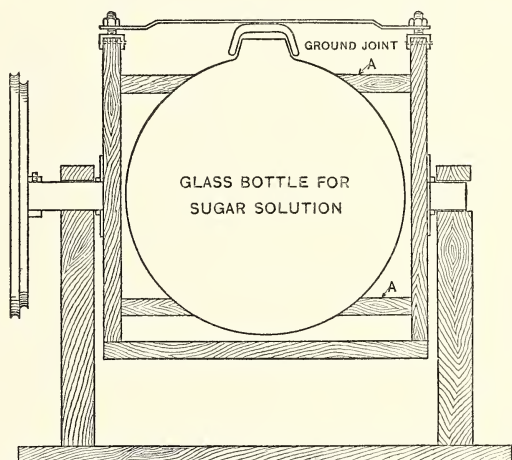


Fig. 11.—Crystallizer

The solid is separated from the mother liquor by a motor-driven centrifugal machine. The centrifuge shown in cross section in Fig. 12 was built by the International Instrument Co. of Cambridge, Mass., in cooperation with the Bureau, and has met all requirements. Its height over all is 2 feet, and it requires but 4 square feet of floor space. All the inside walls of the metal housing, in fact all surfaces with which either the crystals or the mother liquor can come in contact, are silver or nickel plated. The basket is carried on the end of the vertical shaft of a three-fourths horsepower motor. It has an inside diameter of $9\frac{1}{2}$ inches, and is capable of carrying 10 pounds of sugar. Its heavy cover is held in place by a number of set screws A, A, and is readily removable in order to facilitate the removal

of the centrifuged material. The problem of a suitable lining has given considerable trouble. To be satisfactory it must retain very small crystals, permit of free drainage of the mother liquor, and be able to stand the severe strains incidental to high speeds. It is obvious that no single lining

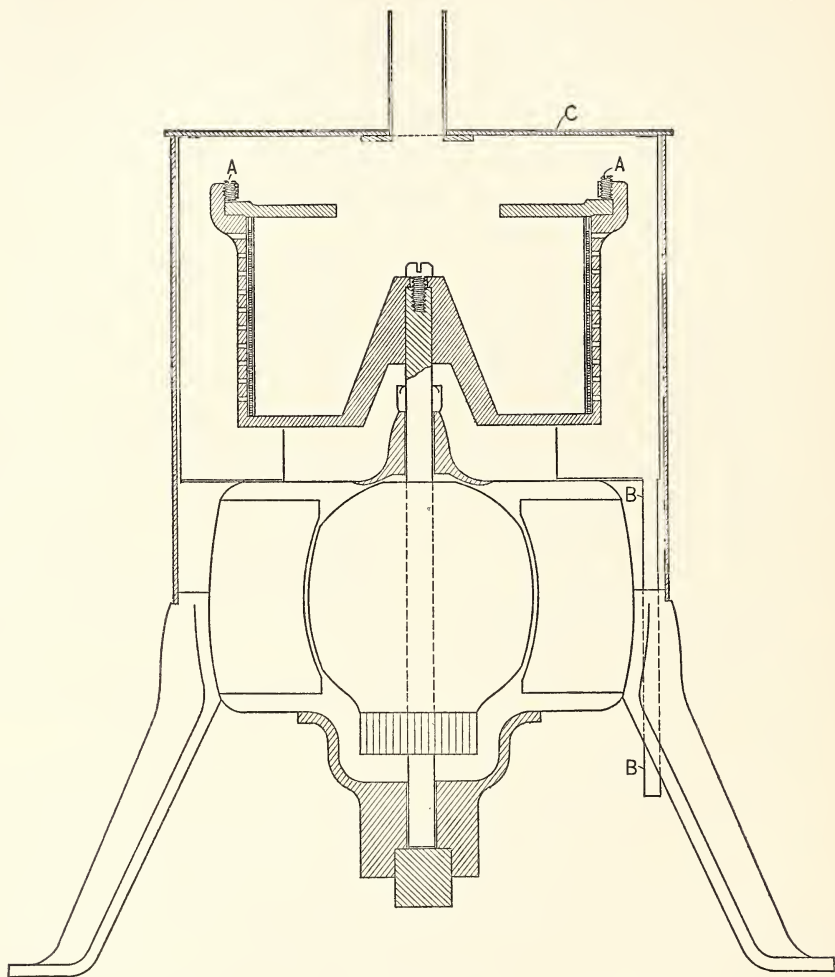


Fig. 12.—Centrifuge

is available that will meet all three requirements. A built-up lining was accordingly resorted to. It consists of two layers. The outer one is the regular copper centrifuge lining⁶¹ with elongated conical holes. The inner one is of 200-mesh brass gauze. Both linings are silver plated.

⁶¹ Manufactured by Fontanie & Co.

In order to hold the flimsy gauze in place it was necessary to fold it over the edge of the heavy copper lining, both above and below, and also around the ends where the vertical edges meet, in every case allowing it to overlap by 1 or 2 centimeters. At the junction of the two edges an extra piece of gauze was fastened to close the crack. Inasmuch as the wear on the gauze lining occurs at the top, it was protected by a piece of thin copper tape which was bent into place. This combination has given excellent results. The mother liquor finds an outlet through the drain B. The small space left between the lid and the frame was closed by stretching a rubber band tightly around the whole machine.

It will be observed that when the centrifuge is in operation with the hinged lid C closed, the contents of the basket as well as the mother liquor are safe from contamination by the air of the room. The speed of rotation of the basket is controlled by a rheostat in series with the motor.

In order to secure a proper distribution of the crystals and insure smooth running of the basket, the crystal mass is introduced while the machine is stationary or running at very low velocity. The speed is gradually increased as the mother liquor runs off until finally the maximum speed of 3000 revolutions per minute is attained.

The substance is then recrystallized in a similar manner, but a second filtration is accomplished through the layer of asbestos in a glass filter shown in Fig. 10, connected directly to the boiling apparatus which supplies the necessary vacuum. This asbestos filter effectively removes the shreds of filter paper which are almost invariably in the filtrate after a filtration through paper. After the solution has passed this filter it comes in contact with nothing but clean glass, and all manipulation of the solution or crystals is carried out under glass cabinets, to reduce possible contamination by dust. The air-dried crystals are powdered to dust in an agate mortar, of which the pestle carries a shield to prevent contamination, and are placed in a vacuum desiccator over lime.

(c) MODIFICATION OF METHOD OF BATES AND JACKSON

A modification of the method of Bates and Jackson has been tried at this Bureau. A 50 per cent solution is clarified by alumina cream, filtered and boiled below 35° C as described above. The boiling is continued to a concentration of 70 to 73 per cent sugar. It is then poured into a crystallizing jar and precipitated by the addition of an equal volume of pure alcohol. The precipitate is separated centrifugally, washed with alcohol, and air dried. This process is repeated. Before bottling it is dried over lime in a vacuum.

The alcohol used for the precipitation of pure sugar should be highly purified with respect to acids or aldehydes. It is not essential that it be dry or free from other members of the alcohol group. The method of purification described by Dunlap⁶² meets these requirements. Dissolve 1.5 g of silver nitrate in 3 cc of water, add to a liter of 95 per cent alcohol in a glass-stoppered cylinder and shake. Dissolve 3 g of caustic potash in 10 cc of warm alcohol and after cooling pour slowly into the alcoholic AgNO_3 solution. Do not shake. Allow to stand over night. Siphon off and distill.

(f) ANALYSIS

(See Fee Schedule 45)

If sugar is to be used for the purpose of standardizing instruments, its purity should be ascertained. This is particularly true of samples required for polarimetric standards and for scientific data of all kinds. There are many sorts of impurities whose presence if undetected may lead to false conclusion in the interpretation of data. These impurities may be grouped into classes for the sake of convenience: (a) Soluble inorganic impurities, (b) soluble organic impurities which reduce alkaline copper, (c) soluble organic impurities which do not reduce alkaline copper, (d) moisture.

Inorganic impurities may readily be recognized by an ash determination. To perform this a quantity of the sugar should be weighed into a very carefully weighed platinum capsule and burned to a char. The char should then be ignited in a muffle furnace at a low red heat, properly below 650°C , until the carbon has been consumed. The ash from a sample of properly purified sugar should not amount to 0.01 per cent. It must be ascertained that the dish itself is of constant weight during a similar period of heating. Samples prepared at this Bureau frequently have an ash content of less than 0.1 mg for a 5 g sample.

The estimation of very small quantities of reducing substances in the presence of the very large quantity of sucrose requires the employment of special methods. The usual methods in which copper sulphate is dissolved in caustic alkali are unsuitable because of the destructive action of the reagent upon the sucrose. The following method used at this Bureau gives reliable results. A solution containing 297 g of KHCO_3 and 1 g $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ is prepared. The potassium bicarbonate should not contain much K_2CO_3 . Fifty cubic centimeters are pipetted into a beaker, boiled for one minute and a solution of 50 cc containing 10 g of the sugar are added, the whole brought to boiling and ebullition continued for two minutes. At the end of this period 100 cc of cold boiled water are added and the precipitate col-

⁶² J. Am. Chem. Soc., 28, 397.

lected on a Gooch-Munroe crucible or on a very closely packed asbestos mat. It has been shown at this Bureau that pure sucrose will produce under this procedure a precipitate of 1.1 mg Cu_2O , while each 0.01 per cent impurity of reducing substance (estimated as invert sugar) increases this precipitate by 1.9 mg. Pure sugar causes a precipitate with all alkaline copper solutions due to its own reducing action. The greater the alkalinity of the copper solution the greater the precipitate, and the greater the copper content the more the precipitate is increased.

The impurities of class c are not so easily detected, but investigations at this Bureau have shown that recrystallization from aqueous solution or by precipitation with alcohol results in every case examined in a purification of the sucrose. This fact can only be shown by a polarimetric study.

In order to dry pure powdered sucrose, care should be exercised not to subject the sample to a prolonged high temperature. Under the influence of an elevated temperature sucrose undergoes a decomposition which is similar to a process of "caramelization." In Table 28 is given the time at each temperature required to form "caramel" equivalent in reducing power to 0.01 per cent of invert sugar. Caramel can be detected by its reducing action on the alkaline copper solution. Finely pulverized sugar can be dried at 70°C in a vacuum in four hours. The moisture remaining will in general amount to less than 0.01 per cent.

XV. ANALYTICAL METHODS FOR SUGAR MIXTURES

(See Fee Schedule 45)

In general in a sugar mixture it is necessary to have as many different analytical processes as there are sugars. These methods should be selected in such a way that the most varied properties of the sugars are represented.

1. TWO SUGARS

(a) COMBINATION OF TWO POLARIMETRIC EQUATIONS

In many instances it is possible to polarize a sugar mixture under conditions sufficiently different to emphasize some striking difference in properties of the two sugars. The variation in specific rotation of the two individuals under the varied conditions must be known in order to substitute in the two corresponding equations. If x and y are the respective percentages of each sugar in the mixture, a and a' the known specific rotations of one of the sugars under the two varied conditions, b and b' those of the second sugar,

$$a x + b y = 100[\alpha]_D \quad (27)$$

$$a' x + b' y = 100[\alpha']_D \quad (28)$$

in which $[\alpha]_D$ and $[\alpha']_D$ are determined experimentally.

The variation of conditions may take the form of a change of temperature, change of solvent, change from neutral to acid solution. Frequently the addition of some foreign substance exerts a striking influence upon the specific rotation of one of the sugars. It must be borne in mind that these influences upon the individual sugars must be known with precision before making application to a mixture.

(b) COMBINATION OF POLARIMETRIC AND DENSIMETRIC EQUATIONS

If no other solid substance than the two sugars is present in a solution it is possible to determine the density or degrees Brix of such solution and set up an equation with the known total sugar present, e. g., $x + y = \text{total sugar}$, where x and y are the respective per cent of each sugar. This procedure does not give the total sugar with high precision because the densities of the various sugars of equal percentage composition are not exactly the same, but for ordinary requirements the approximation is satisfactory. If the only impurity besides the two sugars is an inorganic substance it is a frequent practice to determine the ash and subtract this weight from the total solids as determined by the density or refractive index. This method is, of course, only approximate.

(c) COMBINATION OF POLARIMETRIC AND REFRACTOMETRIC EQUATIONS

Total sugar may also be determined by measuring the refractive index of the solution. Reference to tables gives the total solid with considerable exactitude. $x + y = \text{per cent total solid}$.

(d) COMBINATION OF POLARIMETRIC AND REDUCING POWER EQUATIONS

In case the sample is not a mixture of the two pure sugars it is preferable to combine with the polarimetric equation an equation of combined reducing power in terms of dextrose; that is, the weight of reduced copper converted from the table directly into dextrose. For this purpose reducing sugar is determined in the manner described on page 75. C. A. Browne⁶³ has shown experimentally that the reducing power of a sugar mixture is very exactly the additive property of the constituents.

Let a be the reducing ratio of the first sugar to dextrose.

Let b be the reducing ratio of the second sugar to dextrose.

Then the combined influence of the two reducing sugars is

$$a x + b y = R \quad (29)$$

in which x and y are the respective per cents of the two sugars and R is the per cent of total reducing sugar estimated as dextrose.

⁶³ J. Am. Chem. Soc., 28, p. 439.

(e) MIXTURE OF GLUCOSE AND FRUCTOSE

If the two substances are present in the pure state the first equation may be

$$x + y = \text{per cent total solids} \quad (30)$$

as found by density or refractometer. If the reduction method is used the equation is

$$a x + b y = R, \quad (31)$$

where R is the reducing substance estimated as dextrose.

To find the coefficients for the polarimetric equation, the respective specific rotations for the approximate concentration of each sugar at the temperature of the experiment (see p. 140) may be used, if the specific rotation of the mixture is determined. If the saccharimeter is used, the polarizing power should be expressed in terms of sucrose. The coefficient of each sugar is then the ratio of its specific rotation to that of sucrose, bearing in mind the variation of the respective specific rotations with temperature and concentration. If the specific rotation of sucrose is 66.5, the polarizing ratio of fructose (at 20°, 10 per cent solution) is $\frac{90.18}{66.5} = 1.356 = \alpha$; that of dextrose is $\frac{52.74}{66.5} = 0.793 = \beta$.

The specific rotation of the sucrose may be considered constant, regardless of the concentration, because 66.5 is the value at the hundred point, and all portions of the scale are marked off in exact proportion of concentration. The specific rotation of the other sugars, however, should be corrected for both temperature and concentration.

Formula for polarimetric equation:

Let α be polarizing power of 1st sugar.

Let β be polarizing power of 2d sugar.

Let P be polarizing power of mixture.

then,

$$\alpha x + \beta y = P. \quad (32)$$

The term polarizing power may mean the respective specific rotations, in which case the experimental data P for analyzing the mixture will require a determination of the specific rotation of the mixture; α and β are the respective $[\alpha]_D^{20}$'s of the pure components. Or polarizing power may be determined on the saccharimeter on the sucrose scale. In this case 26 grams of the mixture are dissolved in 100 cc of solution, or the equivalent calculation made by reference to the density of the solution. The polarization is performed in a 200 mm tube in the saccharimeter. In this case the coefficients

α and β are the ratios of polarizing power of the sugar in question to that of sucrose, and may be found from the ratios of the respective specific rotations. By combination of equations (27) and (30) we obtain

$$x = \frac{bP - \beta R}{\alpha b - a\beta} \quad (33)$$

$$y = \frac{\alpha R - aP}{\alpha b - a\beta} \quad (34)$$

$$= \frac{R - ax}{b} \quad (35)$$

2. THREE SUGARS ⁶⁴

(See Fee Schedule 45, f)

For the determination of three sugars three equations are necessary. One of these usually expresses the per cent of total sugar, determined densimetrically, by drying, or by refractive index. If inorganic substances are also present, an approximate correction may be made to the per cent of total solids by subtracting the weight of the ash. A second equation represents total reducing power of the mixture in terms of dextrose. A third represents total or resultant polarizing power.

The equations are

$$x + y + z = \text{Total sugar.} \quad (36)$$

$$ax + by + gz = \text{Total reducing sugar estimated as dextrose.} \quad (37)$$

$$\alpha x + \beta y + \gamma z = P \text{ (polarization).} \quad (38)$$

The second equation represents dextrose as determined by Allihn's method. The third equation again may be computed as specific rotation or it may be determined on the sucrose scale, using the factors given on page 140.

A frequently occurring mixture of three sugars is that of sucrose, dextrose, and levulose. The reducing power of sucrose may be taken as zero. The equations then become

$$x + y + z = \text{Total sugar.}$$

$$x + 0.915 y = R.$$

$$0.793 x - 1.356 y + z = P \text{ (on saccharimeter).}$$

This method gives very good approximation, which may be increased if a small reducing factor is given to sucrose.

In sugar mixtures the approximation may be improved by a direct determination, whenever possible, of any one of the three. Whenever sucrose is

⁶⁴ Browne: Handbook of Sugar Analysis, p. 484.

present it is always possible to determine it directly by means of the double Clerget polarization. In the presence of the two hexoses the acid method should be used with great caution in order to prevent decomposition. The invertase method is preferable because no decomposition can occur under the conditions of the analysis.

XVI. STANDARD SAMPLES

1. SUCROSE

(See Fee Schedule 13)

This Bureau is prepared to issue standard sucrose samples prepared by recrystallization from aqueous solution or by precipitation with alcohol. In the case of each sample the process of purification has been continued until analysis shows a satisfactory product. A certificate of analysis accompanies the sample. The sugar usually contains but little moisture and in a moderately dry atmosphere shows very little hygroscopicity. It is advisable to store the sample in a cool dry place. If placed in a desiccator the drying agent used should be pure. Vapors from impure sulphuric acid or phosphorus pentoxide frequently damage the sugar.

The uses of standard sucrose samples may be briefly stated as follows:

(1) As a primary saccharimetric standard; (2) as a source of pure invert sugar for the standardization of analytical determinations of reducing sugar; (3) as a material for the standardization of bomb calorimeters. It has the advantage of being nonvolatile, and nonhygroscopic. It is rather difficult to ignite and sometimes does not burn completely. It has a heat of combustion of about 3950 calories, or only about half that of the average coal. The more exact value for each sample will be given in the certificate. For details of the standardization of bomb calorimeters, see Circular No. 11.

2. DEXTROSE

(See Fee Schedule 13)

The standard dextrose samples are prepared by purification of the purest glucose of commerce in the manner described on page 81. A certificate of analysis will show the degree of purification of the sample. The standard dextrose sample is intended to assist in research work of a general nature and in particular to serve as a standard reducing sugar for analytical work.

XVII. SPECIAL TESTS

The special requirements of scientific investigators, manufacturers of apparatus, and others for higher precision than is considered in the fore-

going schedules will be met as far as the regular work of the Bureau will permit. The application for a special test should state fully the purpose for which the apparatus has been used or is to be used in the future, the need for the test, and the precision desired. The test should be arranged for by correspondence before shipment of the apparatus. The special fee charged will depend chiefly upon the time consumed and the amount of alteration required in the regular Bureau testing set-ups. An estimate will be given when possible.

XVIII. CERTIFICATES AND STATEMENTS

When apparatus submitted fulfills the requirements for certification, it will be tested and given a certificate of corrections. The certificate can only indicate the corrections of the apparatus at the time of the test, and does not guarantee the constancy of the values. When there are defects which exclude an apparatus from certification, a statement will be rendered giving such information as we have found.

XIX. GENERAL INSTRUCTIONS TO APPLICANTS FOR TESTS

1. APPLICATION FOR TEST

The request for test should be made in writing, addressed to "Bureau of Standards, Washington, D. C.", and should enumerate the articles submitted for test, giving the identification marks of each—for example, maker's name and number—and should state the nature of the test desired.

2. NATURE OF TEST

The classification of tests in this circular should be followed, and the schedule numbers above should be used to indicate the test desired. When the desired test is not included under the regular schedules, the applicant must comply with the requirements for special tests. When apparatus is sent simply for test, without definite instructions, the Bureau will, if practicable, decide upon the nature of the test.

3. IDENTIFICATION MARKS

All packages should bear the shipper's name and address and, when convenient, a list of the contents.

Each separate piece of apparatus, or sample of material should be provided with an identification mark, which in many cases may be the maker's name and number. The identification mark should be given in the application for the test.

4. SHIPPING DIRECTIONS

Apparatus or test specimens should be securely packed in cases or packages which will not be broken in transportation. The shipment in both directions is at the applicant's risk. To facilitate packing and shipping, the tops of the cases should have the return or forwarding address on the under side and should be put on with screws. Transportation charges are payable by the party desiring the test and must be prepaid. Unless otherwise arranged articles will be returned or forwarded by express "collect."

5. RETURN OF APPARATUS

Regular tests will be made in the order in which the applications are received, except as this practice may be varied by grouping similar tests together. It is therefore suggested that the applicant, if possible, make request for a test from two weeks to a month preceding the shipment of the apparatus. This facilitates the work of the Bureau, as well as the prompt return of the apparatus.

6. ADDRESS

Apparatus submitted for test, as well as all correspondence, should be addressed simply "Bureau of Standards, Washington, D. C." Apparatus delivered in person or by messenger should be accompanied by a written request for the test.

7. REMITTANCES

Fees should be sent with the request for test, in accordance with the foregoing schedules, or promptly upon receipt of bill. Certificates are not given nor is apparatus returned until the fees due thereon have been received. Remittances may be made by money order or check drawn to the order of the "Bureau of Standards."

XX. SCHEDULES OF TEST FEES

These schedules will go into effect July 1, 1913, and on and after that date supersede previous schedules. All standardizations at 20° C. unless otherwise specified.

SCHEDULE 41.—Polariscopes for Absolute Measurement—Circular Scales

- (a) Test on five to ten points $\pm 0.01^\circ$, with critical examination of optical parts. \$5.00
 (b) Test on five to ten points, $\pm 0.002^\circ$, with critical examination of optical parts. 10.00

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SCHEDULE 43.—Saccharimeters

(a) Single-quartz wedge, five points.	\$3. 50
(b) Double-quartz wedge, five points on positive wedge and three points on negative wedge.	5. 00
(c) Double quartz wedge, five points on each wedge.	7. 00
(d) Laurent type, five points.	5. 00
(e) Other types, price according to conditions.	

SCHEDULE 44.—Quartz Control Plates, Cover Glasses, and Polariscopes Tubes

(a) Rotation in circular degrees, "yellow-green mercury line" ($\lambda=546.1 \text{ m}\mu$) and sodium lines ($\lambda=589.23 \text{ m}\mu$)	1. 50
(b) Rotation in circular degrees and sugar degrees.	2. 00
(c) Rotation at other temperatures by special arrangement.	
(d) Table of sucrose corrections for temperature.	1. 00
(e) Absence of double refraction in cover glasses. each..	. 05
(f) Determination of the average length of polariscopes observation Tubes to $\pm 0.02 \text{ mm}$ of tubes 100, 200, and 400 mm in length with ends of equal diameter. each..	. 40
(g) Same, for five or more tubes of the same length. each..	. 25
(h) Determination of the average length to $\pm 0.005 \text{ mm}$ of tubes of any length up to 500 mm with ends of equal diameter, provided the construction of the tube justifies the above accuracy each..	1. 00
(i) Determination of the average length to $\pm 0.02 \text{ mm}$ of tubes of any length up to 500 mm with ends of unequal diameters each..	. 75
(j) Same, for five or more tubes of the same length. each..	. 50
(k) Tubes of variable length will be tested for a fee dependent upon the character and amount of work desired.	

SCHEDULE 45.—Sugars and Other Materials

(a) Raw sugars and molasses.	1. 00
(b) Clerget polarization by acid inversion.	1. 50
(c) Clerget polarization by invertase.	2. 00
(d) Polarization at 87°	1. 50
(e) Reducing sugars.	1. 00
(f) Other sugars.	1. 00 to 2. 00
(g) Moisture determination.	. 50
(h) Ash determination.	. 50
(i) Determination of purity of purified sucrose, dextrose, and other sugars.	4. 00
(j) Optical rotation for any substance by special arrangement.	

Extract from Fee SCHEDULE 23.—Flasks

[This schedule is subject to change. See latest edition Circular No. 9]

(a) For testing and stamping, each capacity tested.	. 25
(e) For testing, stamping, and certifying, each capacity tested.	. 35
(g) For testing apparatus intended for temperatures other than 20° C between 15° C and 30° C , additional charges for each piece.	. 20
(h) For testing apparatus of indicated capacity other than in cubic centimeters, additional charges for each piece.	. 20
(i) For preliminary examination of apparatus disqualified for test, charges for each piece.	. 10

Extract from Fee SCHEDULE 10.—Thermometers

[This schedule is subject to change. See latest edition of Circular No. 8]

(a) Determination of corrections in the interval 0° to 100° C to an order of accuracy of 0°.01 or 0°.02, or as accurately as the construction of the thermometer warrants, for each point tested on a single thermometer.	\$0. 30
For the same points tested on additional similar thermometers, per point.	. 20
(b) Determination of corrections in the interval 0° to 100° C to the nearest 0°.1 or 0°.2, for each point tested on a single thermometer.	. 20
For the same points tested on additional similar thermometers, per point.	. 10

Extract from Fee SCHEDULE 11.—Weights

CLASS A

Per weight

(a) Regular test, ⁶⁵ single weights.	1. 00
(b) Regular test, equal weights and sets made up in the usual series.	. 75

CLASS B

(c) Regular test, single weights.	. 60
(d) Regular test, equal weights and sets made up in the usual series.	. 40
(e) For constancy test add one-half of the fee for the regular test.	

SCHEDULE 12

CLASS M

(a) Determination of volume of weight, single weights.	2. 00
(b) Determination of volume, two or more weights.	1. 50
(c) Determination of corrections, single weights.	. 80
(d) Determination of corrections, equal weights or sets made up in the usual series.	. 50
(e) For constancy test add one-half of the fee for determining the corrections.	

CLASS S

(f) Regular test, single weights.	. 60
(g) Regular test, equal weights and sets made up in the usual series.	. 40
(h) For constancy test add one-half of the fee for the regular test.	

SCHEDULE 13

STANDARD SUGAR SAMPLES

Sample No.	
17. Sucrose.	60 g., \$1.50; 120 g., \$2.50
41. Dextrose.	70 g., \$2.00; 140 g., \$3.00

S. W. STRATTON,
Director.

Approved:
E. F. SWEET,
Assistant Secretary.

⁶⁵ The regular test under class A includes the test for constancy, which will mean that the weight will have to be held at the Bureau for a period of over three months.

APPENDIXES

APPENDIX 1

The following regulations promulgated by the United States Treasury Department are reproduced here because of their general interest. They were prepared with the cooperation of the Bureau of Standards.

REGULATIONS GOVERNING THE WEIGHING, TARING, SAMPLING, CLASSIFICATION, AND POLARIZATION OF IMPORTED SUGARS AND MOLASSES

WEIGHING

ART. 1. All imported raw sugars shall be weighed without regard to mark, except as provided in articles 12 and 13. The weigher's return shall show the total weight of the cargo, and shall also show separately for each scale, each half day, the weight of all (a) wet sugar, (b) damaged sugar not wet, (c) ship sweepings, (d) dock sweepings, (e) other sugar. The weigher will make a daily report, as per form Cat. No. 961, to the examiner or sampler in charge, which shall show separately for each scale, each half day, the total number of packages weighed of (a) wet sugar, (b) damaged sugar not wet, (c) ship sweepings, (d) dock sweepings, (e) other sugar. All ship and dock sweepings shall be weighed before the weigher completes his half day's work. In no instance shall the weigher make a return by filling in the weight from the invoice. In the event that a cargo be consigned to two or more consignees, any consignee's sugar shall be treated as a separate cargo, provided separate entry be made by such consignee.

TARING

ART. 2. All tare shall be taken by mark. When sugar is in tierces, hogsheads, barrels, boxes, or irregular packages, actual tare shall be taken. When sugar is in bags, baskets, and mats, actual tare shall be taken as follows:

	Per cent
Marks of less than 1,000.....	4
Marks of 1,000 and less than 4,000.....	3
But in no such mark less than 40 receptacles.	
Marks of 4,000 and less than 10,000.....	2.5
But in no such mark less than 120 receptacles.	
Marks of 10,000 and over.....	1 to 2

However, when sugar is discharged and weighed at points other than refineries, actual tare shall be taken of the largest number of baskets and mats practicable and as nearly as possible the percentage above prescribed. When, in the opinion of the weigher, the condition of the receptacles is such as to make it advisable to tare a larger percentage than that above provided, he shall tare as many receptacles as in his judgment are necessary to

secure a proper tare. All such receptacles are to be thoroughly cleaned by scraping and sweeping before the tare is taken.

A schedule tare is hereby adopted of 2.5 pounds per bag for Cuban sugars imported in bags measuring 29 by 48 inches, and such schedule tare shall be verified from time to time by actual tare. When actual tare is taken the percentage of bags to be tared shall be as above prescribed.

The bags shall be first carefully cleaned by sweeping and scraping and then weighed. They shall then be steamed for 2 hours and dried for 24 hours and again weighed. The difference in the two weights thus found will represent the sugar recovered in the steaming process. From the weight of the dry-cleaned bags there shall be deducted such proportionate weight of the material recovered in the steaming process as the ratio between ninety-five one-hundredths of 1 per cent per pound and the rate of duty chargeable against the cargo as shown by the regular polariscopic test. The weight per bag thus ascertained shall be the actual tare to be allowed upon the entire importation. For convenience in arriving at the proper amount of duty accruing on an importation when actual tare is taken the following procedure will be observed:

The weigher will report, in addition to the total weight of the importation, the weights of the dry-cleaned and steam-cleaned bags separately. From the total weight of the importation the liquidating clerk will deduct the weight of the dry-cleaned bags and will assess upon the net weight the proper rate of duty according to the polariscopic test. To the amount thus ascertained he will then add the duty at the rate of ninety-five one-hundredths of 1 cent per pound upon the quantity of sucrose material recovered in the steaming process; that is, the difference between the weights of the dry-cleaned bags and the steam-cleaned bags.

Schedule tare of 2.5 pounds shall be allowed on all importations, except where the importers shall file a written application representing that the particular importation named in the application contains an excessive number of damaged bags and giving the approximate percentage of the damaged and undamaged bags, and also requesting that actual tare be taken, in which case the surveyor may, with the approval of the collector, if satisfied that the importation includes an excessive number of damaged bags, ascertain the actual tare on the importation in the manner above provided. If the actual tare thus found does not vary from the schedule tare hereinbefore established by more than 5 per cent, then schedule tare only shall be allowed on such importation.

SAMPLING.

ART. 3. All sampling shall be done at the time of weighing. In sampling imported raw sugars a general sample shall be taken; that is, each cargo shall be sampled without regard to marks, except as provided in articles 12 and 13. In the event that a cargo is consigned to two or more consignees, any consignee's sugar shall be treated as a separate cargo, provided separate entry be made by such consignee. A separate general sample shall also be taken of (a) wet sugar, (b) damaged sugar not wet, (c) ship sweepings,

(d) dock sweepings. In taking the general sample 100 per cent of the packages shall be sampled.

It shall be the duty of all samplers to secure a thoroughly representative sample.

In the event that bags are stained from lying in storage, or any other cause, but the sugar not damaged, the sampler in charge, as well as all other samplers, shall exercise every precaution to see that the bags come approximately alternately with the clean and stained sides up. When, in the opinion of the sampler in charge, the bags are not being so discharged, he shall direct the attention of the inspector to the fact and it shall be the duty of the inspector to thereupon stop the discharge of the cargo until the instructions of the sampler are complied with. If, from any cause, in any cargo, the condition of the bags from the ground tier or any other tier shall differ markedly from the condition of the cargo as a whole, such bags shall be treated as damaged. In order to prevent any unnecessary labor and inconvenience in obtaining the sample the inspector shall direct that the packages when discharged from the vessel upon the wharf shall be so placed that the sampler can readily obtain a 100 per cent sample. All ship and dock sweepings shall be sampled before the sampler completes his half day's work.

ART. 4. In the treatment of sugars under these regulations great care will be taken by samplers and other appraising officers to prevent the drying out of the samples. All the sugar buckets in the possession of a sampler shall be either entirely filled or entirely empty, with the exception of one bucket for each general sample. The tag on each bucket must indicate the character of the sugar and the particular half day on which its contents were drawn. The covers of the buckets must be kept carefully closed, except when momentarily opened to receive the sample. The buckets shall be made of heavy galvanized iron and have a height of 31.5 centimeters and a diameter of 18.5 centimeters. All buckets, after being duly labeled for identification, shall be locked before leaving the hatch preparatory to being forwarded to the appraiser's stores. Except as provided in article 11, no general sample of raw sugars will be mixed and prepared on the wharves. The name of the sampling officer responsible for the sampling of each hatch or vessel will be placed on the label, and the examiner or sampler in charge will forward the samples to the appraiser's office with a dock list as per form Cat. No. 994. After the discharge of the cargo has been completed the examiner or sampler in charge shall forward a letter of transmittal to the appraiser as per form Cat. No. 985.

ART. 5. The sugar triers used shall have the following dimensions:

	Short trier	Long trier	Barrel trier
	Centimeters	Centimeters	Centimeters
Length over all.....	40.6	152.4	104.0
Length of spoon.....	22.9	132.1	91.4
Length of shank.....	17.8	20.3	12.7
Length of handle.....	26.7	38.1	30.5
Width of spoon.....	2.7	2.5	2.5
Depth of spoon.....	0.8	1.3	1.1
Diameter of handle.....	3.8	3.8	3.8

ART. 6. Sugar in hogsheads and other wooden packages shall be sampled by putting the long trier diagonally through the package from chime to chime, one trierful to constitute a sample, except in small lots, when an equal number of trierfuls shall be taken from each package to furnish the required amount of sugar necessary to make a sufficient sample. In the sampling of baskets, bags, ceroons, and mats the short trier shall be used, care being exercised to have each sample represent the contents of the package. The greatest precaution shall be taken that the samples from each class of packages shall be kept separate and be uniform in quantity. When the hard condition of the sugar renders the use of the short trier impracticable the sampler in charge shall notify the appraiser immediately and await his instructions. The keys of the sugar buckets shall be in possession of the assistant appraiser or the examiner at the appraiser's office, who shall have sole custody of such keys.

ART. 7. At ports where a number of samplers are employed no one sampler shall be continued in the same sugar district or on the same dock longer than one month. A complete record of the assignment of the examiners and samplers shall be kept and shall be approved by the appraiser.

ART. 8. Sugars conveyed on lighters from the place of original discharge before samples have been taken shall not be removed therefrom until notice has been given by the inspector to the examiner or sampler in charge of the time of their proposed removal.

ART. 9. Inspectors are directed to exercise a personal supervision over the discharging of sugar cargoes. They shall have their permits indorsed by the examiner or sampler in charge after the samples have been obtained in accordance with these regulations. Dock sweepings shall be gathered up and weighed and sampled when discharging has stopped for any cause. The inspector is directed to keep, in every instance, an accurate account of the kind and number of packages of sweepings, which he shall indorse on the back of the permit or lighter manifest before it is presented to the appraiser's office for indorsement. If no sweepings are found the inspector shall indorse the permit or manifest accordingly.

ART. 10. In cases where vessels discharge in one district and the sugars are lightered to another before sampling, the manifest which accompanied the lighter and is delivered to the inspector in charge of the district where such sugars are to be weighed and sampled shall be presented to the examiner or sampler in charge for his indorsement, the same as in the case of an original permit. The inspector in charge of such district shall be held responsible for the treatment of all such sugars under these regulations, the same as if working under the original permit.

ART. 11. All sugar samples drawn on any given half day shall reach the examining room in the appraiser's stores not later than the close of the first official half day following, except where the place of discharge is more than 15 miles distant from the appraiser's stores. Whenever practicable the samples for each half day will be forwarded to the appraiser's stores as soon as the half day is completed. When sugars are discharged at places where the distance makes it impracticable for the regular conveyance to call for

the samples, and where special provision is made by contract for other means of transportation, an official shall be detailed by the appraiser to take charge of such samples until they reach the appraiser's stores. When such transportation owing to accident or storm, is interfered with, an officer may be detailed by the appraiser to go to such place, mix the samples, and bring a sufficient part of the mixed samples to the appraiser's stores.

ART. 12. All raw sugars from the Philippine Islands shall be weighed and sampled as grades 1, 2, and 3. When in the opinion of the examiner or sampler in charge the markings upon the packages do not correctly represent the grade of the sugar contained therein, the grade designation marked upon the packages shall be ignored and the packages shall thereupon be weighed and sampled according to the grade actually found by the samplers in each package. In every instance as nearly 100 per cent of the packages shall be sampled as is practicable.

ART. 13. When practicable all refined sugars shall be sampled with a trier specially provided for that purpose, and such percentage shall be sampled as in the judgment of the examiner or sampler in charge will afford a fair representation of the mark. When there is doubt whether a package of sugar is raw or refined, or whether a raw sugar is above or below No. 16 Dutch standard in color, such package shall be sampled in not less than two places to fairly represent the contents, and such samples shall aggregate not less than eleven ounces. The package shall be numbered by the weigher and weighed separately, and the weigher's return shall show the number and weight of such package.

ART. 14. The utmost care must be taken to keep all the apparatus used in the process of sampling sugar clean and absolutely dry. Suitable cleaning and polishing materials will be supplied to the samplers, who are hereby instructed to always have their implements in perfect condition. The sampler shall frequently and thoroughly clean his trier with a scraper provided for that purpose. Failure to observe these requirements will be reported at once to the appraiser by the examiner or the sampler in charge, and such failure will be regarded as sufficient cause for suspension.

ART. 15. Of importations of molasses, as near as possible to 100 per cent of the packages shall be sampled. If any package or packages invoiced as molasses shall, in the judgment of the sampling officer, have the appearance of sirup of cane juice, a separate sample from each such package, properly labeled as to mark and character, shall be taken for examination as hereinafter provided.

ART. 16. In drawing samples of molasses care shall be taken to secure a fair representation and an equal amount of the contents from each package. Packages of the same size shall be sampled in groups of not more than 25; samples from all of the packages of each group being put into a bucket. An accurate tally shall be kept and with each bucket shall be reported the number of packages the samples therein represent. The dock list accompanying the sample buckets shall convey the same information and account for every package of the mark. Packages of different size, although invoiced

and permitted under the same mark, shall be separately sampled, tested, and returned for classification. Molasses discharged from tank vessels shall be sampled as it is pumped from the tanks, a sample of uniform quantity being drawn at either regular intervals of approximately fifteen minutes or for every 5,000 gallons discharged.

ART. 17. Inasmuch as the absorption of sea water or moisture reduces the polariscopic test of sugar, there shall be no allowance on account of increased weight of sugar importations due to unusual absorption of sea water or of moisture while on the voyage of importation. That portion of the cargo claimed by the importer to have absorbed sea water or moisture on the voyage of importation shall be sampled, tested, and classified separately. This claim must be made at the time of weighing. Special care must be taken that such sugars are sampled so as to fairly represent the contents of the packages.

ART. 18. Sugar discharged during a rain or snow storm shall be sampled under cover. When this is impracticable, or if in the judgment of the appraiser, the sugar may be damaged by reason of the stress of weather the inspector shall immediately stop the discharge of the cargo.

ART. 19. All sugars and sugar products discharged under night permits shall be sampled when weighed.

ART. 20. Sugar closets in the districts shall be substantially built and secured by locks furnished by the Department. The keys of the district closets and offices shall be in the possession of the sampling officers on the districts, who, with the sworn officers in charge of the conveyances, shall have sole custody of such keys.

ART. 21. All officers of the customs having duties in connection with the treatment for duty of imported sugars are expected to cooperate and to use the utmost care and diligence so that the work of sampling and classification may be facilitated. The examiners and samplers in charge shall be held responsible by the appraiser for the strict and impartial enforcement of these regulations, and to this end they shall be notified relative to the time of discharge and weighing of sugar cargoes in their respective districts by the inspector or weigher in charge of the same.

ART. 22. The appraiser shall notify the collector of the boundaries of sugar districts and the location of the examiner's or sampler's office in each district, and such information will be furnished by the collector to the inspectors and weighing officers. The collector shall furnish each inspector and weigher with a copy of these regulations.

CLASSIFICATION

ART. 23. All samples shall be carefully examined with reference to color by the Dutch standard after they have reached the classification room in the appraiser's stores. Should any portion thereof be found to be close to No. 16 Dutch standard in color, it shall be examined and passed upon by two experts in the appraiser's office, and in case of disagreement between them as to the number of the color according to the Dutch standard, the appraiser shall designate some person who will decide between them.

ART. 24. Samples of raw sugar found to be above No. 16 Dutch standard in color shall be preserved and sealed in glass bottles labeled with the name of the importer, date of importation, place whence imported, name of vessel, classification, number and character of packages, and the names of the examiners who passed the same. The bottles containing such samples shall be retained by the appraiser for at least one month after the return of the invoice to the collector.

ART. 25. Great care shall be exercised to have all samples mixed and forwarded to the laboratory for test at the earliest possible date. Under no circumstances shall the contents of more than three sugar buckets be mixed together. In mixing the greatest care shall be exercised by the examiners to have the contents of the sugar buckets thoroughly mixed. Too much stress can not be laid upon this exceedingly important point.

ART. 26. From the sample prepared by mixing the contents of not more than three buckets duplicate samples shall be prepared by closely packing two tin cans full of sugar and transmitted forthwith to the laboratories for polariscopic test. A third portion, consisting of about 3 pounds, shall be placed in a glass jar to constitute a reserve sample. In all cases the jars must be firmly packed full of sugar before closing and so sealed as to make them air-tight. Such samples after being properly labeled for identification shall be held in safe custody by the appraiser for use when required.

When preparing samples for the laboratory from the reserve jars the entire contents shall be taken out and remixed in order that the moisture may again be evenly distributed throughout the sample.

ART. 27. The tin cans used in transmitting the samples to the laboratories for polariscopic test shall have a height of 11.5 centimeters and a diameter of 8 centimeters. They shall be practically air-tight, the seamless lid fitting snugly over the rim, which is topped by a seamless band. No cans shall be used for this purpose that have not been made on the dies owned by the Department.

ART. 28. In transmitting the samples from the examiner's room to the laboratory they shall be indicated only by serial numbers, the key of which shall be kept in a permanent form under the special direction of the appraiser, and the laboratory officers shall not be informed in any manner as to the identity of such samples.

ART. 29. Not less than two complete tests by different experts shall be made of each sample sent to the laboratory. Should the polarization shown by the two tests be 92° S. (sugar degree) or above, and should they agree within 0.2° S., the average of the two polarizations shall be accepted as the test of the sample. If the polarization should be less than 92° S., and they agree within 0.3° S., the average of the two shall be accepted as the test of the sample.

ART. 30. If the polarizations of the two tests do not correspond within the limits of accuracy prescribed in article 29, a third test of the sample shall be made by a third expert, when practicable, and of the three tests so made the average of the two most closely corresponding shall be accepted as the

test of the sample, provided the polarizations of the two last-mentioned tests correspond within the limits of accuracy prescribed in article 29; and provided further, that if one of the three tests so made be the average of the other two tests and correspond with the same within the limits of accuracy prescribed in article 29, then such test shall be accepted as the test of the sample.

ART. 31. When two of the three tests do not correspond within the limits of accuracy prescribed in article 29, all three tests shall be discarded and the sample shall again be tested as provided in articles 29 and 30.

ART. 32. The polarizations returned by the chemist in charge shall be permanently entered in a record of tests, form Cat. No. 987, together with the accepted test of each sample. Should such accepted tests of duplicate samples provided for in article 26 correspond within 0.3° S. the average of of the two shall be taken as the true polariscopic test of the sugar. All appraisement sheets, forms Cat. Nos. 990 1/8 and 990 2/8, of each cargo shall be filed separately by the loose leaf system for a permanent record.

ART. 33. When the accepted tests of the two samples do not agree within three-tenths of 1° S., a third sample, to be known as the reserve sample, shall be made up from the reserve portion, and treated as a regular sample. The tests of the reserve sample having been duly recorded, the accepted tests of the three samples shall be considered together. Of the three separate tests so recorded the average of the two most closely corresponding shall be taken as the test of the sugar; but if one of the said tests be the average of the other two it shall be taken as the correct test.

ART. 34. When the test of the sugar has been determined the appraiser shall immediately notify the importer of the average test of the cargo and also the quantity and test of each lot from which such average test is obtained. Should the importer within two official days after such notice has been sent to him by the appraiser claim an error in the test so reported and request a retest, such retest may be granted, provided, on evidence furnished, such claim shall appear to the appraiser to be well founded. Before granting retest the appraiser shall require of the importer any information he may deem desirable relative to the samples and polarizations used in the settlement tests. Before any sugar invoice is passed the appraiser shall require the importer to furnish the settlement tests, and in no instance shall a retest be granted when the difference between the appraiser's test and the settlement test is shown to be less than four-tenths of 1° S. Samples for retest shall be made up from the reserve sample and shall be treated in all respects as provided for the original tests.

All requests for retests of sugar shall be properly filed and a record thereof shall be kept by the appraiser on form Cat. No. 982.

ART. 35. In case of retest made under the provisions of article 34 the test upon which the sugar shall be classified shall be the average of the test and the retest unless it can be shown to the satisfaction of the appraiser that either the test or the retest is in error, in which event the test not in error shall be taken as the basis of classification.

ART. 36. In all cases where in the judgment of the appraiser an error has been made the reserve sample may be resorted to by the appraiser at any time before he has made his return on the invoice for the purpose of determining and correcting such error.

ART. 37. Molasses having been sampled in groups of 25 packages or less as provided for in article 16, a test shall be found for the can of samples representing each group in the manner prescribed in articles 29 to 33, inclusive, and the test for classification shall be the average of the ascertained tests of the several groups so found based upon the proportion of the entire number of packages of the same size which each of the said lot represents, provided the test of any group is not above 56° S.

The test for classification of molasses imported in tank vessels shall be an average of the tests of all the various cans of samples drawn during the discharge of the vessel, as provided for in article 16.

In the examination of molasses all samples shall be handled as expeditiously as possible, in order that they may not be affected by fermentation. In sending samples to the laboratory, the small 1-pound cans containing the same shall be given a serial number that will insure as early a test as possible.

Importations invoiced and entered as molasses, possessing in any degree the taste or smell or other characteristics of sirup of cane juice, shall be subjected to chemical analysis, and determinations shall be made of the percentage of water and of the cane sugar in the dry substance.

ART. 38. In the event of the polarization of the dry substance being above 75° S., the samples shall be held to be sirup of cane juice within the meaning of the tariff; but should the polarization of the dry substance not exceed 75° S. the sample shall be designated as molasses, unless there be other evidence of a conclusive character to warrant its designation as sirup of cane juice.

ART. 39. It may be here stated as the view of the Department that molasses, within the meaning of the tariff, is the liquid residuum drained or purged from raw sugar, and hence is the result of a process of manufacture which has for its object the formation of sugar; while on the other hand, sirup of cane juice is the juice of the cane highly concentrated, but not to the point of crystallization, and hence is the result of a process of manufacture having for its chief object the concentration of the juice to the point of preservation but short of crystallization.

ART. 40. In the laboratory a permanent record shall be kept of all samples received from the examiner's room, which shall be entered therein by their serial numbers the order in which they are received; and the chemist in charge shall report all tests made and recorded of such samples, severally, including the third and fourth tests, when made, to the assistant appraiser or examiner in charge of classifications.

ART. 41. When an invoice of sugar or molasses has been passed, the appraiser shall at once send written notice to the importer, informing him of the test for classification of his importation.

ART. 42. In order that the results of the testing of imported sugars at the several ports may be compared, it is directed that on each alternate day, beginning with Monday, a sample of sugar shall be tested at each of the ports of Boston, New York, Philadelphia, and New Orleans, and at the same time duplicate samples of the same sugars shall be exchanged for tests between the appraisers of the said ports, and the Bureau of Standards, Washington. The duplicates shall be sent in the tin can prescribed in article 27, which must be firmly packed full of sugar and sealed air-tight with paraffin. The samples shall be numbered at each port of importation from 1 upward, beginning each year with the first official day in January, and the duplicates shall be marked for identification with the same number, the name of the importing port, and the date of test at such port.

ART. 43. The duplicate samples must be tested as soon as they have been received and shall be sent to the laboratory under regular serial numbers, the identifying marks having been removed, after having been first entered in a special record, together with their respective serial numbers. Samples at the port of importation and those sent for exchange shall be tested in all respects as provided in articles 29 to 31, both inclusive, and the separate tests of such samples, together with the accepted tests, shall be promptly reported from each port to the Department, under their respective identifying marks.

ART. 44. On each alternate day, beginning with Tuesday, a sample of sugar will be tested in the dry substance at each of the ports named in article 42, and duplicate samples of the same sugar shall at the same time be exchanged as directed in article 42. The duplicates shall be prepared, marked for identification, and forwarded in manner as provided in article 42. Such samples shall be sent to the laboratory as soon as received, under their respective identifying marks, and reports of tests shall be promptly forwarded from each port to the Department under such marks. Such reports shall show the direct polarization, the per cent of moisture, and the test in the dry substance. When sugars are imported and tested at any port other than those named in article 42, samples shall be tested in the dry substance at the port of importation and duplicate samples shall be transmitted for like test to the Bureau of Standards. The samples shall be prepared and reports of said tests shall be made in all respects as herein prescribed for samples exchanged and tested at the said first-named ports. Reports of tests prescribed in this and the preceding paragraph shall be made on form Cat. No. 990. All requests by the Secretary of the Treasury for retests of duplicate samples at the ports mentioned in article 42 shall be immediately complied with and the retest completed not later than the close of the first official day after the receipt of such request. When for any reason the retests requested by the Secretary of the Treasury are not completed by the close of the first official day after the receipt of the request, the retests shall not be made, and the appraiser shall furnish the Secretary of the Treasury with a detailed statement why said retests were not made as herein provided.

ART. 45. Paragraph 212 of the tariff act of July 24, 1897, provides in part that sugars after being refined, when tintured, colored, or in any way adulterated, shall pay special rates of duty. In view of this provision appraising officers will cause all refined sugars to be subjected to expert examination, and will report to the collector whether the same after being refined have been tintured, colored, or in any way adulterated. At ports where the Government has no facilities for making such expert examination samples of all refined sugars imported shall be forwarded to the nearest appraiser, at New York, Boston, Philadelphia, New Orleans, or San Francisco, who will cause the necessary expert examination to be made and report the results to the collector of the port of importation.

ART. 46. Sugars which are subject to the additional duty imposed under the provisions of section 5 of the tariff act because of any bounty or grant paid or bestowed on the exportation of the same from the country of production, and the amount of such bounty or grant is made dependent on the polariscopic test of the sugar, must be subjected to such test, and report thereof will be made to the collector on the invoice for use in liquidation; but all hard refined sugars, such as cut-loaf, crystals, crushed or granulated, shall be deemed to have tested at least 99.5° S. when exported from the country of production. In all cases where the classification of imported sugar for the assessment of duty is liable to be contested, either on the question of its polariscopic test, or on one arising under the provision of law referred to in the preceding article, representative samples of such sugars shall be preserved in manner as provided in article 26, and such samples shall be held until the return of the invoice to the collector.

ART. 47. All samples of sugar sent to the laboratory for test must be preserved as nearly as possible in the same condition as when received, and shall be returned therefrom to the examining room in such condition with the reports of the tests. All samples tested for exchange and all exchange samples, as soon as they have been returned from the laboratory, shall be labeled with their identifying mark, securely sealed air-tight, and held in safe custody in the examining room thirty days from the date of test for such further test or investigation as may be ordered by the Department. In case any exchange sample has been received at any port not properly filled and sealed as herein prescribed, the appraiser at the port of receipt shall immediately notify the appraiser at the port of transmittal, and shall also report the facts to the Department.

ART. 48. All persons shall be denied admission to the examining rooms of the appraiser's office, except officers and employees whose duties require them to have access thereto. This provision must be strictly enforced.

POLARIZATION

ART. 49. The expression "testing * * * degrees by the polariscope," occurring in Schedule E, paragraph 209 of the tariff act, shall be construed to mean the percentage of pure sucrose contained in the sugar as ascertained by polarimetric estimation.

ART. 50. Plans for laboratories for the testing of sugar must be approved by the Secretary of the Treasury. The room used for the purpose shall be one that is as far removed as possible from the vibration of machinery; it must be well lighted and have some means of artificial heat, so that the temperature may be controlled, and shall not be too near any source of heat which can not be controlled. The polariscopes shall be placed in the darkest portion of the room whenever possible, and the top of the table upon which they are placed shall be surrounded on three sides by blackened partitions or walls not less than 3 feet in height. If necessary suitable curtains may be hung around the polariscope to cut off interfering lights. The surroundings of the polariscope shall be such as always to permit the air from the remainder of the room to circulate around the instruments with the greatest freedom. The separation of the lamp from the instruments will be accomplished by the wall around the top of the table. The opening in the partition between the lamp and the instrument shall be as small as possible and yet allow sufficient light for the proper illumination of the polariscope. The polariscopes shall not be near ovens, assay furnaces, hot-water heaters, or any other source of heat, and must not be exposed to the direct rays of the sun.

ART. 51. All thermometers, flasks, weights, polariscope tubes, polariscope tube cover glasses, quartz control plates, and polariscopes, used in the work of testing sugar, shall be standardized at the Bureau of Standards, Department of Commerce, and with the exception of the polariscope tube cover glasses and weights, shall be marked with the initials "U. S. C. S.," and bear the stamp of the Bureau of Standards. No test of sugar will be made with apparatus which is not properly marked unless special authority is given by the Secretary of the Treasury.

ART. 52. All the apparatus used in the work of testing sugar by the polariscope shall be standardized at a temperature of 20° C.

ART. 53. All thermometers shall have the centigrade scale and be graduated to not less than one-tenth of a degree.

ART. 54. The flasks shall have a height of 130 millimeters; the neck shall be 70 millimeters in length and have an internal diameter of not less than 11.5 millimeters and not more than 12.5 millimeters. The upper end of the neck shall be flared, and the graduation marks shall be not less than 30 millimeters from the upper end and 15 millimeters from the lower end of the neck.

All flasks shall be standardized to contain 100 metric cubic centimeters at 20° C. The glass funnels used in filtering shall have a diameter of approximately 90 millimeters. The cylinders shall have a height of approximately 125 millimeters and a diameter of approximately 40 millimeters.

ART. 55. Only brass weights shall be used in testing sugar, and shall be forwarded to the Bureau of Standards for standardizing not less than once a year. A sufficient number of standardized duplicate weights shall be kept in reserve in each laboratory to take the place of those being standardized.

ART. 56. The length of all polariscope tubes shall be either 100 millimeters ± 0.01 millimeter or 200 millimeters ± 0.01 millimeter, and the diameter of the opening through the tube shall be not less than 9 millimeters. No tube shall be retained in use that has become bent or has had its threads injured sufficiently to make the adjustment of the cap difficult.

ART. 57. All quartz control plates shall be mounted in a brass retaining box which shall exert absolutely no pressure whatever upon the plate and yet allow it minimum play. Each plate will be accompanied by a table, signed by the Director of the Bureau of Standards, giving its exact value at different temperatures from 10° to 35° C.

ART. 58. All polariscopes shall be so adjusted that when a 200-millimeter tube filled with the standard sugar solution is polarized at 20° C. the instrument shall read 100° S. $\pm 0.01^{\circ}$ S. All points on the scale shall indicate percentages of the standard solution. The standard sugar solution shall be prepared by dissolving 26 grams of pure sugar in pure water and making up the volume to 100 metric cubic centimeters, all weighings to be made in air with brass weights and the volume to be completed at 20° C. A length of 200 millimeters of the standard sugar solution shall be considered to give a rotation of 40.728° , for light of wave length 5,461 centimeters $\times 10^{-8}$.

ART. 59. All polariscopes used in the testing of imported sugars shall have a double quartz wedge compensation and a polarizing system known as the Lippich half shadow. The field of the polariscope will be divided into halves by a vertical line, and in no instance shall a reading of the scale be made unless in the opinion of the observer the halves are of exactly equal intensity.

If when the polariscope is empty and the field a match the zero of the movable scale shall fail to correspond with the zero of the vernier by more than 0.3° S. (sugar degrees), they shall be made to coincide by turning the small nipple on the left-hand side of the instrument.

In testing the instrument by means of the quartz control plate not less than four careful readings shall be made. After the average of these readings has been corrected for the error in the zero point it should equal the value stamped upon the plate within 0.05° S. If such is not the case the polariscope shall be readjusted until the difference is not greater than 0.05° S.

When taking the reading on the quartz control plate referred to in article 64, the deviation of the zero point shall be neglected after the instrument has been found to be accurately adjusted. The total correction for the instrument shall then be found by means of the table accompanying the plate and the reading of a thermometer placed close to the polariscope.

The method of determining and applying the total correction shall be as follows: Let a sugar solution polarize 80.5° S. The control plate had polarized 91.4° S. The temperature of the room during both observations was 25° C. From the table the value of the control plate at 25° C. is 91.7° S.

The reading is therefore 0.3 too low and 0.3 shall be added to the reading of the sugar solution, making the corrected polarization 80.8° S.

The zeros of the upper scale and its vernier shall be kept in exact coincidence and the scale securely clamped in that position.

The source of light may be either an incandescent gas mantle or white light electric lamp. The radiating source shall not be less than 200 millimeters distant from the polarizing end, the best position of the source being determined by carefully adjusting it back and forth until the illumination of the field is absolutely uniform and a maximum.

ART. 60. After the can of sugar referred to in article 27 has reached the laboratory its contents shall be thoroughly mixed while in the can by stirring with a spoon just before the weighing is made. In case the sugar contains hard lumps not readily crushed and mixed by stirring it shall be mixed in a mortar or by other adequate means. After mixing, 26 grams are weighed on the balance in the tared German silver dish furnished for this purpose. Care must be taken that the operations of mixing and weighing are not unduly prolonged, otherwise the sample may easily suffer considerable loss of moisture, especially in a warm room. The weighed portion of sugar is washed by means of a jet of water into a 100 cubic centimeter flask, the dish being well rinsed three or four times and the rinsings added to the contents of the flask. The water used must be either distilled water or clear water which has been found to have no optical activity. After the dish has been thoroughly rinsed enough water is added to bring the contents of the flask to about 80 cubic centimeters, and it is gently rotated until all the sugar is dissolved. The flask shall be held by the neck between the fingers or with the thumb and finger and the bulb not handled during this operation. Care must be taken that no particle of the sugar or solution is lost. To determine whether all the sugar is dissolved the flask is held above the level of the eye, in which position any undissolved crystals can be easily seen at the bottom. The character of the solution is now observed. If it be colorless, or of a very light straw color and not opalescent so that it will give a clear, transparent liquid on filtration through paper, the volume shall be made up directly with water to the 100 cubic centimeter mark on the flask.

ART. 61. If a clear, transparent liquid is not obtained as directed in article 60, a clarifying agent shall be added. In that event, before making up to the mark a solution of subacetate of lead is added, which is prepared by boiling three parts by weight of acetate of lead, one part by weight of oxide of lead, and ten parts by weight of water, until the reaction is complete. The filtered solution should have a density of about 1.25. Solid subacetate of lead may be substituted for the normal salt and oxide in the preparation of the solution.

After adding the solution of subacetate of lead the flask must be gently shaken, so as to mix it with the water solution. If the proper amount has been added, the precipitate will usually subside rapidly; but if not, the operator may judge of the completeness of the precipitation by holding

the flask above the level of the eye and allowing an additional drop of subacetate of lead to flow down the side of the flask into the solution. If this drop leaves a clear track along the glass through the solution, it indicates that the precipitation is complete. If, on the other hand, all trace of the drop is lost on entering the solution, it indicates that an additional small quantity of the subacetate of lead is required. The operator must learn by experience the point where the addition should cease; an excess of subacetate of lead solution should never be used.

ART. 62. The solution shall be made up to the mark by the addition of distilled water in the following manner: The flask, grasped by the neck between the thumb and finger, shall be held before the operator in an upright position, so that the mark is at the level of the eye, and water is added, drop by drop, from a siphon bottle or wash bottle, until the lowest point of the curve or meniscus formed by the surface of the liquid just touches the mark. If bubbles hinder the operation, they may be broken up by adding a single drop of ether, or a spray from an ether atomizer, before making up to the mark. After making up to volume drops of water adhering to the neck above the meniscus shall be removed. The mouth of the flask shall be tightly closed with the thumb and the contents of the flask are thoroughly mixed by turning and shaking. The entire solution shall be poured upon the filter.

The funnel and the vessel used to receive the filtrate must be perfectly dry. The first portion of the filtrate, about 20 to 30 cubic centimeters, should be rejected entirely. It may be necessary to return subsequent portions to the filter until the liquid passes through perfectly clear.

If a satisfactory clarification has not been obtained, the entire operation must be repeated, since only with solutions that are entirely clear and bright can accurate polarimetric observations be made.

ART. 63. If after having proceeded as directed in article 62, the solution be still too dark to polarize, even in the 100-millimeter tube, as in the case of dark-colored molasses, it shall be decolorized by means of bone-black. The use of this clarifying agent shall be avoided if possible, however, on account of its well-known property of absorbing sugar. If its use is found absolutely necessary, a fresh solution is prepared, and before filtration 4 or 5 grams of dry boneblack are placed in the apex of the filter paper. The first 50 or 60 cubic centimeters of the filtrate must be rejected.

When a sufficient quantity of the clear liquid has passed through the filter the 200-millimeter polariscope tube shall be filled with it. The 100-millimeter tube should never be used except in the rare cases when, notwithstanding all the means used to effect the proper decolorization of the solution it is still too dark to polarize in the 200-millimeter tube. In such cases the shorter tube may be used and its reading multiplied by 2 but the zero deviation must then be determined and applied to the product. This will give the reading which would have been obtained if a 200-millimeter tube could have been used, and it only remains to apply the correction determined by the use of the control plate, as directed in article 59.

Example

Solution reads in 100-millimeter tube.....	47. 0
Multiplied by 2.....	2. 0
Product.....	94. 0
Zero reads plus 0.3.....	0. 3
Solution would read in 200-millimeter tube.....	93. 7
Reading of control plate.....	90. 4
Sugar value of control plate.....	90. 5
Instrument too low by.....	0. 1
Add 0.1 to.....	93. 7
Correct polarization of solution.....	93. 8

Before filling the tube it must either be thoroughly washed and dried or rinsed several times with a portion of the solution itself. The cover glasses must also be clean and dry and without serious defects or scratches. Under no circumstances after sufficient liquid has passed through the filter shall more than 12 minutes elapse before the tube is filled. Unnecessary warming of the tube by the hands during the filling must be avoided. It is closed at one end with the screw cap and cover glass and grasped by the other end with the thumb and finger. The solution is poured in until its curved surface projects slightly above the opening, the air bubbles allowed time to rise, and the cover glass pushed horizontally over the end of the tube in such a manner that the excess of liquid is carried over the side, leaving the cover glass exactly closing the tube, with no air bubbles beneath it and with no portion of the liquid upon its upper surface. If this result is not attained the operation shall be repeated, the cover glass being rubbed clean and dry, and the solution again brought up over the end by adding a few more drops. The cover glass being in position, the tube shall be closed by screwing on the cap. The greatest care must be observed in screwing down the caps that they do not press too tightly upon the cover glasses. By such pressure the glasses themselves may become optically active and cause erroneous readings when placed in the instrument. It shall therefore be ascertained that the rubber washers are in position over the cover glasses and the caps shall be screwed on lightly. A cover glass that has once been compressed may part with its acquired optical activity very slowly and not less than seven official days shall be allowed to elapse before it is used again.

ART. 64. Before the polariscopic reading on the polariscope tube shall be taken an observation on the quartz control plate shall be made as directed in article 59. The tube must be read without altering the position of the instrument relative to the light or changing the character of the light in any way. When a series of successive polarizations is made under the same conditions as regards temperature, position of the instrument with relation to the light, intensity of the light, etc., the observation on the control plate need not be made before each polarization; one such observation shall be sufficient for the entire series. The control observation must be repeated

oftener if the observer has the slightest reason to think that any of the factors just indicated have been altered. After the polariscope tube has been placed in the polariscope the observing telescope shall be so adjusted as to bring the dividing line between the two halves of the field into sharp focus and at the same time vanish as nearly as possible. This condition must be carefully fulfilled before any observation is taken. Each polariscopic tube shall be read on two different instruments by the same observer, and not less than three careful readings of the tube shall be made on each instrument. After the average of these three readings has been corrected by means of the quartz control plate, as directed in article 59, it shall be taken as the polarization of the tube on that polariscope. The average of the two averages obtained from the two polariscopes shall be taken as the final polarization of the tube.

ART. 65. For the determination of moisture in sugars dry approximately 4 grams in a nickel dish of a diameter of 55 mm. and a height of 15 mm. Each sample shall be subjected to a temperature of 98° C. for two hours.

For the determination of moisture in molasses, sirups, and massecuites, dry, approximately 2 grams in a flat dish of not less than 70 mm. in diameter. Each sample shall be subjected to a temperature of 98° C. for a period of two hours. Care must be taken to run the liquid in a film over the bottom of the dish and to retain in a horizontal position during the entire operation.

ART. 66. No regulation relative to weighing, taring, sampling, classification, and polarization of imported sugars shall be so construed as to permit of mixing together centrifugal, beet, molasses, Philippine, or any sugar different in character from those mentioned for the purpose of weighing, taring, sampling, classification, or polarization.

ART. 67. These regulations shall be and remain in full force and effect from and after the date of approval thereof; and all rules, orders, or regulations heretofore issued or promulgated with reference to weighing, taring, sampling, and classification of imported sugars and molasses are hereby revoked and rendered null and void.

APPENDIX 2—TABLES

TABLE 8

Apparent Weight (in Grams) of Water in Air

[This table gives the apparent weight for temperatures between 15° and 30° C, humidity 50 per cent, uncorrected barometer reading 76 cm, of certain volumes of water weighed with brass weights. The table may be conveniently employed to determine definite volumes of water for calibrating instruments. The air is assumed to be at the same temperature as the water]

Temperature in degrees C	2000 cc	1000 cc	500 cc	400 cc	300 cc	250 cc	150 cc
15	1996.11	998.05	499.03	399.22	299.42	249.51	149.71
16	1995.80	997.90	498.95	399.16	299.37	249.48	149.68
17	1995.48	997.74	498.87	399.10	299.32	249.43	149.66
18	1995.13	997.56	498.78	399.03	299.27	249.39	149.63
19	1994.76	997.38	498.69	398.95	299.21	249.34	149.61
20	1994.36	997.18	498.59	398.87	299.15	249.30	149.58
21	1993.95	996.97	498.49	398.79	299.09	249.24	149.55
22	1993.51	996.76	498.38	398.70	299.03	249.19	149.51
23	1993.06	996.53	498.26	398.61	298.96	249.13	149.48
24	1992.58	996.29	498.15	398.52	298.89	249.07	149.44
25	1992.09	996.04	498.02	398.42	298.81	249.01	149.41
26	1991.57	995.79	497.89	398.31	298.74	248.95	149.37
27	1991.04	995.52	497.76	398.21	298.66	248.88	149.33
28	1990.49	995.24	497.62	398.10	298.57	248.81	149.29
29	1989.92	994.96	497.48	397.98	298.49	248.74	149.24
30	1989.33	994.66	497.33	397.87	298.40	248.67	149.20

TABLE 9

Temperature Correction for Glass Volumetric Apparatus

[This table gives the correction to be added to actual capacity (determined at certain temperatures) to give the capacity at the standard temperature, 20° C. Conversely by subtracting the corrections from the indicated capacity of an instrument standard at 20° C the corresponding capacity at other temperatures is obtained. The table assumes for the cubical coefficient of expansion of glass 0.000025 per degree centigrade. The coefficients of expansion of glasses used for volumetric instruments vary from 0.000023 to 0.000028]

Temperature in °C	2000 cc	1000 cc	500 cc	400 cc	300 cc	250 cc
15	+0.25	+0.12	+0.06	+0.05	+0.04	+0.031
16	+ .20	+ .10	+ .05	+ .04	+ .03	+ .025
17	+ .15	+ .08	+ .04	+ .03	+ .02	+ .019
18	+ .10	+ .05	+ .02	+ .02	+ .02	+ .012
19	+ .05	+ .02	+ .01	+ .01	+ .01	+ .006
21	— .05	— .02	— .01	— .01	— .01	— .006
22	— .10	— .05	— .02	— .02	— .02	— .012
23	— .15	— .08	— .04	— .03	— .02	— .019
24	— .20	— .10	— .05	— .04	— .03	— .025
25	— .25	— .12	— .06	— .05	— .04	— .031
26	— .30	— .15	— .08	— .06	— .04	— .038
27	— .35	— .18	— .09	— .07	— .05	— .044
28	— .40	— .20	— .10	— .08	— .06	— .050
29	— .45	— .22	— .11	— .09	— .07	— .056
30	— .50	— .25	— .12	— .10	— .08	— .062

TABLE 10

Tolerances and Precision of Corrections for Weights

Denomination	Tolerance classes M and S	Precision of corrections, values given to—			Tolerance classes A and B	Tolerance class C ⁶⁶
		Class M	Class S	Class A		
kg	mg	mg	mg	mg	mg	mg
20	100	10	100	.....	.....	600
10	50	10	10	.....	.....	400
5	25	1	10	.....	.....	250
2	10	1	10	.....	.....	150
1	5	1	10	.....	.....	100
g	.....	.....	⁶⁷ 1	.....	.....	.....
500	2.5	1	1	.....	.....	70
200	1.0	0.1	1	.....	.....	40
100	.5	.1	1	.....	.....	30
.....	.....	.....	⁶⁷ 0.1	.....	.....	.....
50	.3	.1	.1	.....	.....	20
26	.2	.1	.1	0.1	2.0	10
20	.2	.01	.1	.....	.....	10
13	.15	.01	.1	.1	1.5	7
10	.15	.01	.1	.....	.....	7
5	.15	.01	.1	.....	.....	5
2	.10	.01	.1	.....	.....	3
1	.10	.01	.1	.....	.....	2
mg	.....	.....	⁶⁷ .01	.....	.....	.....
500	.05	.001	.01	.....	.....	1.5
200	.05	.001	.01	.....	.....	.7
100	.05	.001	.01	.....	.....	.5
50	.03	.001	.01	.....	.....	.35
20	.03	.001	.01	.....	.....	.20
10	.02	.001	.01	.....	.....	.15
5	.02	.001	.01	.....	.....	.10
2	.01	.001	.01	.....	.....	.05
1	.01	.001	.01	.....	.....	.04
0.5	.01	.001	.01	.....	.....	.....
.2	.01	.001	.01	.....	.....	.....
.1	.01	.001	.01	.....	.....	.....

⁶⁶ Weights whose errors are not larger than these tolerances will be accepted for regular test and certification, but analytical weights need not conform to the class C requirements as to material, structure, etc.

⁶⁷ Single reference standards of these denominations will be certified to the higher degree of precision.

TABLE 11

Table for Correction of the Readings of the Brix Spindle when the Reading is Made at Other than the Standard Temperature, 17.5°

[For temperatures below 17.5° the correction is to be subtracted]

Temperature	Degree Brix of the solution												
	0	5	10	15	20	25	30	35	40	50	60	70	75
°C													
0	0.17	0.30	0.41	0.52	0.62	0.72	0.82	0.92	0.98	1.11	1.22	1.25	1.29
5	0.23	0.30	0.37	0.44	0.52	0.59	0.65	0.72	0.75	0.80	0.88	0.91	0.94
10	0.20	0.26	0.29	0.33	0.36	0.39	0.42	0.45	0.48	0.50	0.54	0.58	0.61
11	0.18	0.23	0.26	0.28	0.31	0.34	0.36	0.39	0.41	0.43	0.47	0.50	0.53
12	0.16	0.20	0.22	0.24	0.26	0.29	0.31	0.33	0.34	0.36	0.40	0.42	0.46
13	0.14	0.18	0.19	0.21	0.22	0.24	0.26	0.27	0.28	0.29	0.33	0.35	0.39
14	0.12	0.15	0.16	0.17	0.18	0.19	0.21	0.22	0.22	0.23	0.26	0.28	0.32
15	0.09	0.11	0.12	0.14	0.14	0.15	0.16	0.17	0.16	0.17	0.19	0.21	0.25
16	0.06	0.07	0.08	0.09	0.10	0.10	0.11	0.12	0.12	0.12	0.14	0.16	0.18
17	0.02	0.02	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.06
18	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02
19	0.06	0.08	0.08	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.08	0.06
20	0.11	0.14	0.15	0.17	0.17	0.18	0.18	0.18	0.19	0.19	0.18	0.15	0.11
21	0.16	0.20	0.22	0.24	0.24	0.25	0.25	0.25	0.26	0.26	0.25	0.22	0.18
22	0.21	0.26	0.29	0.31	0.31	0.32	0.32	0.32	0.33	0.34	0.32	0.29	0.25
23	0.27	0.32	0.35	0.37	0.38	0.39	0.39	0.39	0.40	0.42	0.39	0.36	0.23
24	0.32	0.38	0.41	0.43	0.44	0.46	0.46	0.47	0.47	0.50	0.46	0.43	0.40
25	0.37	0.44	0.47	0.49	0.51	0.53	0.54	0.55	0.55	0.58	0.54	0.51	0.48
26	0.43	0.50	0.54	0.56	0.58	0.60	0.61	0.62	0.62	0.66	0.62	0.58	0.55
27	0.49	0.57	0.61	0.63	0.65	0.68	0.68	0.69	0.70	0.74	0.70	0.65	0.62
28	0.56	0.64	0.68	0.70	0.72	0.76	0.76	0.78	0.78	0.82	0.78	0.72	0.70
29	0.63	0.71	0.75	0.78	0.79	0.84	0.84	0.86	0.86	0.90	0.86	0.80	0.78
30	0.70	0.78	0.82	0.87	0.87	0.92	0.92	0.94	0.94	0.98	0.94	0.88	0.86
35	1.10	1.17	1.22	1.24	1.30	1.32	1.33	1.35	1.36	1.39	1.34	1.27	1.25
40	1.50	1.61	1.67	1.71	1.73	1.79	1.79	1.80	1.82	1.83	1.78	1.69	1.65
50	-----	2.65	2.71	2.74	2.78	2.80	2.80	2.80	2.80	2.79	2.70	2.56	2.51
60	-----	3.87	3.88	3.88	3.88	3.88	3.88	3.88	3.90	3.82	3.70	3.43	3.41
70	-----	5.17	5.18	5.20	5.14	5.13	5.10	5.08	5.06	4.90	4.72	4.47	4.35
80	-----	-----	6.62	6.59	6.54	6.46	6.38	6.30	6.26	6.06	5.82	5.50	5.33
90	-----	-----	8.26	8.16	8.06	7.97	7.83	7.71	7.58	7.30	6.96	6.58	6.37
100	-----	-----	10.01	9.87	9.72	9.56	9.39	9.21	9.03	8.64	8.22	7.76	7.42

TABLE 12⁶⁸

Stanek's Table for Determination of Water Content of Raw Sugars by Readings on the Immersion Refractometer

Refractometer reading	Per cent water	Refractometer reading	Per cent water	Refractometer reading	Per cent water	Refractometer reading	Per cent water	Refractometer reading	Per cent water
88.0	4.900	88.8	3.900	89.6	2.900	90.4	1.900	91.2	0.900
88.1	4.775	88.9	3.775	89.7	2.775	90.5	1.775	91.3	0.775
88.2	4.650	89.0	3.650	89.8	2.650	90.6	1.650	91.4	0.650
88.3	4.525	89.1	3.525	89.9	2.525	90.7	1.525	91.5	0.525
88.4	4.400	89.2	3.400	90.0	2.400	90.8	1.400	91.6	0.400
88.5	4.275	89.3	3.275	90.1	2.275	90.9	1.275	91.7	0.275
88.6	4.150	89.4	3.150	90.2	2.150	91.0	1.150	91.8	0.150
88.7	4.025	89.5	3.025	90.3	2.025	91.1	1.025	91.9	0.025

Correction for Hundredths Estimated on Scale

0.03° estimated on scale = -0.04% water.

0.05° estimated on scale = -0.06% water.

0.07° estimated on scale = -0.09% water.

⁶⁸ See page 69.

TABLE 13

Table of Temperature Corrections for Determination of Water in Raw Sugars

Temperature, °C	Subtracted from refractometer reading	Temperature, °C	Added to refractometer reading	Temperature, °C	Added to refractometer reading	Temperature, °C	Added to refractometer reading
15.0	0.72	17.6	0.03	20.2	0.82	22.8	1.62
15.1	0.70	17.7	0.06	20.3	0.85	22.9	1.65
15.2	0.67	17.8	0.09	20.4	0.88	23.0	1.69
15.3	0.64	17.9	0.12	20.5	0.91	23.1	1.72
15.4	0.61	18.0	0.15	20.6	0.94	23.2	1.75
15.5	0.58	18.1	0.18	20.7	0.97	23.3	1.78
15.6	0.55	18.2	0.21	20.8	1.00	23.4	1.81
15.7	0.52	18.3	0.24	20.9	1.03	23.5	1.85
15.8	0.49	18.4	0.27	21.0	1.06	23.6	1.88
15.9	0.46	18.5	0.30	21.1	1.09	23.7	1.91
16.0	0.44	18.6	0.33	21.2	1.12	23.8	1.96
16.1	0.41	18.7	0.36	21.3	1.15	23.9	1.99
16.2	0.38	18.8	0.39	21.4	1.18	24.0	2.03
16.3	0.35	18.9	0.42	21.5	1.22	24.1	2.06
16.4	0.32	19.0	0.45	21.6	1.25	24.2	2.09
16.5	0.29	19.1	0.48	21.7	1.28	24.3	2.12
16.6	0.26	19.2	0.51	21.8	1.31	24.4	2.15
16.7	0.23	19.3	0.54	21.9	1.34	24.5	2.19
16.8	0.20	19.4	0.57	22.0	1.37	24.6	2.22
16.9	0.17	19.5	0.61	22.1	1.41	24.7	2.25
17.0	0.15	19.6	0.64	22.2	1.44	24.8	2.29
17.1	0.12	19.7	0.67	22.3	1.47	24.9	2.32
17.2	0.09	19.8	0.70	22.4	1.50	25.0	2.35
17.3	0.06	19.9	0.73	22.5	1.53	25.1	2.38
17.4	0.03	20.0	0.76	22.6	1.56	25.2	2.42
17.5	0.00	20.1	0.79	22.7	1.59	25.3	2.45

TABLE 14

Hübener's Table for Determining Percentages by Weight of Sucrose in Sugar Solution from Readings of the Zeiss Immersion Refractometer

Scale reading of refractometer	Per cent sucrose	Scale reading of refractometer	Per cent sucrose	Scale reading of refractometer	Per cent sucrose	Scale reading of refractometer	Per cent sucrose	Scale reading of refractometer	Per cent sucrose	Scale reading of refractometer	Per cent sucrose	Scale reading of refractometer	Per cent sucrose
15.0	0.00	17.0	0.53	19.0	1.05	21.0	1.58	23.0	2.11	25.0	2.64	27.0	3.16
.1	.03	.1	.56	.1	.08	.1	.61	.1	.13	.1	.66	.1	.19
.2	.05	.2	.58	.2	.11	.2	.64	.2	.16	.2	.69	.2	.21
.3	.08	.3	.61	.3	.13	.3	.66	.3	.19	.3	.71	.3	.24
.4	.11	.4	.64	.4	.16	.4	.69	.4	.21	.4	.74	.4	.26
.5	.13	.5	.66	.5	.19	.5	.71	.5	.24	.5	.77	.5	.29
.6	.16	.6	.69	.6	.21	.6	.74	.6	.26	.6	.79	.6	.32
.7	.19	.7	.71	.7	.24	.7	.77	.7	.29	.7	.82	.7	.34
.8	.21	.8	.74	.8	.26	.8	.79	.8	.32	.8	.84	.8	.37
.9	.24	.9	.77	.9	.29	.9	.82	.9	.34	.9	.87	.9	.40
16.0	.26	18.0	.79	20.0	.32	22.0	.84	24.0	.37	26.0	.90	28.0	.42
.1	.29	.1	.82	.1	.34	.1	.87	.1	.40	.1	.92	.1	.45
.2	.32	.2	.84	.2	.37	.2	.90	.2	.42	.2	.95	.2	.48
.3	.34	.3	.87	.3	.40	.3	.92	.3	.45	.3	.98	.3	.50
.4	.37	.4	.90	.4	.42	.4	.95	.4	.48	.4	3.00	.4	.53
.5	.40	.5	.92	.5	.45	.5	.98	.5	.50	.5	.03	.5	.56
.6	.42	.6	.95	.6	.48	.6	2.00	.6	.53	.6	.05	.6	.58
.7	.45	.7	.98	.7	.50	.7	.03	.7	.56	.7	.08	.7	.61
.8	.48	.8	1.00	.8	.53	.8	.05	.8	.58	.8	.11	.8	.64
.9	.50	.9	.03	.9	.56	.9	.08	.9	.61	.9	.13	.9	.66

TABLE 14—Continued

Scale reading of re-frac-tometer	Per cent sucrose	Scale reading of re-frac-tometer	Per cent sucrose	Scale reading of re-frac-tometer	Per cent sucrose	Scale reading of re-frac-tometer	Per cent sucrose	Scale reading of re-frac-tometer	Per cent sucrose	Scale reading of re-frac-tometer	Per cent sucrose	Scale reading of re-frac-tometer	Per cent sucrose
29.0	3.69	35.0	5.26	41.0	6.82	47.0	8.34	53.0	9.80	59.0	11.27	65.0	12.69
.1	.71	.1	.29	.1	.84	.1	.36	.1	.83	.1	.29	.1	.72
.2	.74	.2	.32	.2	.87	.2	.39	.2	.85	.2	.32	.2	.74
.3	.77	.3	.34	.3	.90	.3	.41	.3	.88	.3	.34	.3	.76
.4	.79	.4	.37	.4	.92	.4	.44	.4	.90	.4	.36	.4	.79
.5	.82	.5	.40	.5	.95	.5	.46	.5	.92	.5	.39	.5	.81
.6	.84	.6	.42	.6	.97	.6	.49	.6	.95	.6	.41	.6	.83
.7	.87	.7	.45	.7	7.00	.7	.51	.7	.97	.7	.44	.7	.86
.8	.90	.8	.48	.8	.03	.8	.53	.8	10.00	.8	.46	.8	.88
.9	.92	.9	.50	.9	.05	.9	.56	.9	.03	.9	.49	.9	.90
30.0	.95	36.0	.53	42.0	.08	48.0	.58	54.0	.05	60.0	.51	66.0	.93
.1	.98	.1	.56	.1	.10	.1	.60	.1	.07	.1	.53	.1	.95
.2	4.00	.2	.58	.2	.13	.2	.63	.2	.10	.2	.56	.2	.97
.3	.03	.3	.61	.3	.15	.3	.66	.3	.12	.3	.58	.3	13.00
.4	.05	.4	.64	.4	.18	.4	.68	.4	.15	.4	.60	.4	.03
.5	.08	.5	.66	.5	.20	.5	.70	.5	.17	.5	.63	.5	.05
.6	.11	.6	.69	.6	.23	.6	.73	.6	.19	.6	.66	.6	.07
.7	.13	.7	.71	.7	.26	.7	.75	.7	.22	.7	.68	.7	.09
.8	.16	.8	.74	.8	.28	.8	.78	.8	.24	.8	.70	.8	.11
.9	.19	.9	.77	.9	.31	.9	.80	.9	.27	.9	.73	.9	.14
31.0	.21	37.0	.79	43.0	.33	49.0	.83	55.0	.29	61.0	.75	67.0	.16
.1	.24	.1	.82	.1	.36	.1	.85	.1	.32	.1	.78	.1	.18
.2	.26	.2	.84	.2	.39	.2	.88	.2	.34	.2	.80	.2	.20
.3	.29	.3	.87	.3	.41	.3	.90	.3	.36	.3	.83	.3	.23
.4	.32	.4	.90	.4	.43	.4	.92	.4	.39	.4	.85	.4	.25
.5	.34	.5	.92	.5	.46	.5	.95	.5	.41	.5	.88	.5	.27
.6	.37	.6	.95	.6	.49	.6	.97	.6	.44	.6	.90	.6	.29
.7	.39	.7	.98	.7	.51	.7	9.00	.7	.46	.7	.92	.7	.32
.8	.42	.8	6.00	.8	.54	.8	.03	.8	.49	.8	.95	.8	.34
.9	.45	.9	.03	.9	.56	.9	.05	.9	.51	.9	.97	.9	.36
32.0	.48	38.0	.05	44.0	.59	50.0	.07	56.0	.53	62.0	12.00	68.0	.38
.1	.50	.1	.08	.1	.61	.1	.10	.1	.56	.1	.03	.1	.40
.2	.53	.2	.10	.2	.64	.2	.12	.2	.58	.2	.05	.2	.43
.3	.56	.3	.13	.3	.66	.3	.15	.3	.60	.3	.07	.3	.45
.4	.58	.4	.15	.4	.69	.4	.17	.4	.63	.4	.09	.4	.48
.5	.61	.5	.17	.5	.72	.5	.19	.5	.66	.5	.12	.5	.50
.6	.64	.6	.20	.6	.74	.6	.22	.6	.68	.6	.14	.6	.52
.7	.66	.7	.23	.7	.77	.7	.24	.7	.70	.7	.16	.7	.54
.8	.69	.8	.26	.8	.79	.8	.27	.8	.73	.8	.18	.8	.57
.9	.71	.9	.28	.9	.82	.9	.29	.9	.75	.9	.21	.9	.59
33.0	.74	39.0	.31	45.0	.84	51.0	.32	57.0	.78	63.0	.23	69.0	.61
.1	.77	.1	.33	.1	.87	.1	.34	.1	.80	.1	.25	.1	.63
.2	.79	.2	.36	.2	.90	.2	.36	.2	.83	.2	.28	.2	.66
.3	.82	.3	.39	.3	.92	.3	.39	.3	.85	.3	.30	.3	.68
.4	.84	.4	.41	.4	.95	.4	.41	.4	.88	.4	.32	.4	.70
.5	.87	.5	.43	.5	.97	.5	.44	.5	.90	.5	.35	.5	.73
.6	.90	.6	.46	.6	8.00	.6	.46	.6	.92	.6	.37	.6	.75
.7	.92	.7	.49	.7	.03	.7	.49	.7	.95	.7	.39	.7	.77
.8	.95	.8	.51	.8	.05	.8	.51	.8	.97	.8	.42	.8	.79
.9	.98	.9	.54	.9	.07	.9	.53	.9	11.00	.9	.44	.9	.82
34.0	5.00	40.0	.56	46.0	.10	52.0	.56	58.0	.03	64.0	.46	70.0	.84
.1	.03	.1	.59	.1	.12	.1	.58	.1	.05	.1	.49	.1	.87
.2	.05	.2	.61	.2	.15	.2	.60	.2	.07	.2	.51	.2	.89
.3	.08	.3	.64	.3	.17	.3	.63	.3	.10	.3	.53	.3	.92
.4	.11	.4	.66	.4	.19	.4	.66	.4	.12	.4	.56	.4	.94
.5	.13	.5	.69	.5	.22	.5	.68	.5	.15	.5	.58	.5	.96
.6	.16	.6	.72	.6	.24	.6	.70	.6	.17	.6	.60	.6	.98
.7	.19	.7	.74	.7	.27	.7	.73	.7	.19	.7	.63	.7	14.00
.8	.21	.8	.77	.8	.29	.8	.75	.8	.22	.8	.65	.8	.03
.9	.24	.9	.79	.9	.32	.9	.78	.9	.24	.9	.67	.9	.05

TABLE 14—Continued

Scale reading of re-fractometer	Per cent sucrose	Scale reading of re-fractometer	Per cent sucrose	Scale reading of re-fractometer	Per cent sucrose	Scale reading of re-fractometer	Per cent sucrose	Scale reading of re-fractometer	Per cent sucrose	Scale reading of re-fractometer	Per cent sucrose	Scale reading of re-fractometer	Per cent sucrose
71.0	14.07	76.0	15.20	81.0	16.31	86.0	17.44	91.0	18.53	96.0	19.59	101.0	20.66
.1	.09	.1	.22	.1	.33	.1	.47	.1	.55	.1	.61	.1	.68
.2	.11	.2	.24	.2	.35	.2	.49	.2	.57	.2	.63	.2	.70
.3	.14	.3	.26	.3	.38	.3	.51	.3	.59	.3	.66	.3	.72
.4	.16	.4	.28	.4	.40	.4	.53	.4	.61	.4	.68	.4	.74
.5	.18	.5	.30	.5	.42	.5	.55	.5	.63	.5	.70	.5	.76
.6	.20	.6	.32	.6	.44	.6	.58	.6	.66	.6	.72	.6	.78
.7	.23	.7	.34	.7	.47	.7	.60	.7	.68	.7	.74	.7	.80
.8	.25	.8	.36	.8	.49	.8	.62	.8	.70	.8	.76	.8	.82
.9	.27	.9	.38	.9	.51	.9	.64	.9	.72	.9	.78	.9	.85
72.0	.29	77.0	.40	82.0	.54	87.0	17.66	92.0	.74	97.0	.80	102.0	.87
.1	.32	.1	.42	.1	.56	.1	.68	.1	.76	.1	.82	.1	.89
.2	.34	.2	.44	.2	.59	.2	.71	.2	.78	.2	.85	.2	.91
.3	.36	.3	.46	.3	.61	.3	.73	.3	.80	.3	.87	.3	.93
.4	.38	.4	.49	.4	.63	.4	.75	.4	.82	.4	.89	.4	.95
.5	.40	.5	.51	.5	.65	.5	.77	.5	.85	.5	.91	.5	.97
.6	.43	.6	.54	.6	.68	.6	.79	.6	.87	.6	.93	.6	21.00
.7	.45	.7	.56	.7	.70	.7	.82	.7	.89	.7	.95	.7	.02
.8	.48	.8	.59	.8	.72	.8	.84	.8	.91	.8	.97	.8	.04
.9	.50	.9	.61	.9	.74	.9	.86	.9	.93	.9	20.00	.9	.06
73.0	.52	78.0	.63	83.0	.76	88.0	.89	93.0	.95	98.0	.02	103.0	.08
.1	.54	.1	.65	.1	.79	.1	.91	.1	.97	.1	.04	.1	.10
.2	.57	.2	.68	.2	.81	.2	.93	.2	19.00	.2	.06	.2	.13
.3	.59	.3	.70	.3	.83	.3	.95	.3	.02	.3	.08	.3	.15
.4	.61	.4	.72	.4	.85	.4	.98	.4	.04	.4	.10	.4	.17
.5	.63	.5	.74	.5	.88	.5	18.00	.5	.06	.5	.13	.5	.19
.6	.66	.6	.76	.6	.90	.6	.02	.6	.08	.6	.15	.6	.21
.7	.68	.7	.79	.7	.92	.7	.04	.7	.10	.7	.17	.7	.23
.8	.70	.8	.81	.8	.95	.8	.06	.8	.13	.8	.19	.8	.25
.9	.73	.9	.83	.9	.97	.9	.08	.9	.15	.9	.21	.9	.27
74.0	.75	79.0	.85	84.0	17.00	89.0	.10	94.0	.17	99.0	20.23	104.0	.29
.1	.77	.1	.88	.1	.02	.1	.13	.1	.19	.1	.25	.1	.31
.2	.79	.2	.90	.2	.04	.2	.15	.2	.21	.2	.27	.2	.34
.3	.82	.3	.92	.3	.07	.3	.17	.3	.23	.3	.29	.3	.36
.4	.84	.4	.95	.4	.09	.4	.19	.4	.25	.4	.31	.4	.38
.5	.87	.5	.97	.5	.11	.5	.21	.5	.27	.5	.34	.5	.40
.6	.89	.6	16.00	.6	.13	.6	.23	.6	.29	.6	.36	.6	.42
.7	.92	.7	.03	.7	.15	.7	.25	.7	.31	.7	.38	.7	.44
.8	.94	.8	.05	.8	.18	.8	.27	.8	.34	.8	.40	.8	.47
.9	.96	.9	.07	.9	.20	.9	.29	.9	.36	.9	.42	.9	.49
75.0	.98	80.0	.09	85.0	.22	90.0	.31	95.0	.38	100.0	20.44	105.0	.51
.1	15.00	.1	.11	.1	.24	.1	.34	.1	.40	.1	.47	.1	.53
.2	.03	.2	.13	.2	.27	.2	.36	.2	.42	.2	.49	.2	.55
.3	.05	.3	.16	.3	.29	.3	.38	.3	.44	.3	.51	.3	.57
.4	.07	.4	.18	.4	.31	.4	.40	.4	.47	.4	.53	.4	.59
.5	.09	.5	.20	.5	.33	.5	.42	.5	.49	.5	.55	.5	.61
.6	.11	.6	.22	.6	.35	.6	.44	.6	.51	.6	.57	.6	.63
.7	.13	.7	.24	.7	.38	.7	.47	.7	.53	.7	.59	.7	.66
.8	.16	.8	.27	.8	.40	.8	.49	.8	.55	.8	.61	.8	.68
.9	.18	.9	.29	.9	.42	.9	.51	.9	.57	.9	.63	.9	.70
												106.0	21.71

TABLE 15

Geerligs' Table for Dry Substance in Sugar-house Products by Abbe Refractometer, at 28° C

[Intern. Sugar J., 10. p. 69.]

Index Refraction	Per cent dry. Substance	Decimals		Index Refraction	Per cent dry. Substance	Decimals	
1.3335	1	0.0001=0.05	0.0010=0.75	1.4104	46	0.0005=0.25	0.0016=0.8
1.3349	2	0.0002=0.1	0.0011=0.8	1.4124	47	0.0006=0.3	0.0017=0.85
1.3364	3	0.0003=0.2	0.0012=0.8	1.4145	48	0.0007=0.35	0.0018=0.9
1.3379	4	0.0004=0.25	0.0013=0.85	1.4166	49	0.0008=0.4	0.0019=0.95
1.3394	5	0.0005=0.3	0.0014=0.9	1.4186	50	0.0009=0.45	0.0020=1.0
1.3409	6	0.0006=0.4	0.0015=1.0	1.4207	51	0.0010=0.5	0.0021=1.0
1.3424	7	0.0007=0.5		1.4228	52	0.0011=0.55	
1.3439	8	0.0008=0.6		1.4249	53		
1.3454	9	0.0009=0.7		1.4270	54		
1.3469	10						
1.3484	11	0.0001=0.05		1.4292	55	0.0001=0.05	0.0013=0.55
1.3500	12	0.0002=0.1		1.4314	56	0.0002=0.1	0.0014=0.6
1.3516	13	0.0003=0.2		1.4337	57	0.0003=0.1	0.0015=0.65
1.3530	14	0.0004=0.25		1.4359	58	0.0004=0.15	0.0016=0.7
1.3546	15	0.0005=0.3		1.4382	59	0.0005=0.2	0.0017=0.75
1.3562	16	0.0006=0.4		1.4405	60	0.0006=0.25	0.0018=0.8
1.3578	17	0.0007=0.45		1.4428	61	0.0007=0.3	0.0019=0.85
1.3594	18	0.0008=0.5		1.4451	62	0.0008=0.35	0.0020=0.9
1.3611	19	0.0009=0.6		1.4474	63	0.0009=0.4	0.0021=0.9
1.3627	20	0.0010=0.65		1.4497	64	0.0010=0.45	0.0022=0.95
1.3644	21	0.0011=0.7		1.4520	65	0.0011=0.5	0.0023=1.0
1.3661	22	0.0012=0.75		1.4543	66	0.0012=0.5	0.0024=1.0
1.3678	23	0.0013=0.8		1.4567	67		
1.3695	24	0.0014=0.85		1.4591	68		
1.3712	25	0.0015=0.9		1.4615	69		
1.3729	26	0.0016=0.95		1.4639	70		
				1.4663	71		
				1.4687	72		
1.3746	27	0.0001=0.05	0.0012=0.6	1.4711	73	0.0001=0.0	0.0015=0.55
1.3764	28	0.0002=0.1	0.0013=0.65	1.4736	74	0.0002=0.05	0.0016=0.6
1.3782	29	0.0003=0.15	0.0014=0.7	1.4761	75	0.0003=0.1	0.0017=0.65
1.3800	30	0.0004=0.2	0.0015=0.75	1.4786	76	0.0004=0.15	0.0018=0.65
1.3818	31	0.0005=0.25	0.0016=0.8	1.4811	77	0.0005=0.2	0.0019=0.7
1.3836	32	0.0006=0.3	0.0017=0.85	1.4836	78	0.0006=0.2	0.0020=0.75
1.3854	33	0.0007=0.35	0.0018=0.9	1.4862	79	0.0007=0.25	0.0021=0.8
1.3872	34	0.0008=0.4	0.0019=0.95	1.4888	80	0.0008=0.3	0.0022=0.8
1.3890	35	0.0009=0.45	0.0020=1.0	1.4914	81	0.0009=0.35	0.0023=0.85
1.3909	36	0.0010=0.5	0.0021=1.0	1.4940	82	0.0010=0.35	0.0024=0.9
1.3928	37	0.0011=0.55		1.4966	83	0.0011=0.4	0.0025=0.9
1.3947	38			1.4992	84	0.0012=0.45	0.0026=0.95
1.3966	39			1.5019	85	0.0013=0.5	0.0027=1.0
1.3984	40			1.5046	86	0.0014=0.5	0.0028=1.0
1.4003	41			1.5073	87		
				1.5100	88		
1.4023	42	0.0001=0.05	0.0012=0.6	1.5127	89		
1.4043	43	0.0002=0.1	0.0013=0.65	1.5155	90		
1.4063	44	0.0003=0.15	0.0014=0.7				
1.4083	45	0.0004=0.2	0.0015=0.75				

TABLE 16

Table of Corrections for the Temperature

Temperature of the prisms in ° C	Dry substance												
	0	5	10	15	20	25	30	40	50	60	70	80	90
	Subtract—												
20	0.53	0.54	0.55	0.56	0.57	0.58	0.60	0.62	0.64	0.62	0.61	0.60	0.58
21	0.46	0.47	0.48	0.49	0.50	0.51	0.52	0.54	0.56	0.54	0.53	0.52	0.50
22	0.40	0.41	0.42	0.42	0.43	0.44	0.45	0.47	0.48	0.47	0.46	0.45	0.44
23	0.33	0.33	0.34	0.35	0.36	0.37	0.38	0.39	0.40	0.39	0.38	0.38	0.38
24	0.26	0.26	0.27	0.28	0.28	0.29	0.30	0.31	0.32	0.31	0.31	0.30	0.30
25	0.20	0.20	0.21	0.21	0.22	0.22	0.23	0.23	0.24	0.23	0.23	0.23	0.22
26	0.12	0.12	0.13	0.14	0.14	0.14	0.15	0.15	0.16	0.16	0.16	0.15	0.14
27	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.07
	Add—												
	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.07
	0.12	0.12	0.13	0.14	0.14	0.14	0.15	0.15	0.16	0.16	0.16	0.15	0.14
29	0.20	0.20	0.21	0.21	0.22	0.22	0.23	0.23	0.24	0.23	0.23	0.23	0.22
30	0.26	0.26	0.27	0.28	0.28	0.29	0.30	0.31	0.32	0.31	0.31	0.30	0.30
31	0.33	0.33	0.34	0.35	0.36	0.37	0.38	0.39	0.40	0.39	0.38	0.38	0.38
32	0.40	0.41	0.42	0.42	0.43	0.44	0.45	0.47	0.48	0.47	0.46	0.45	0.44
33	0.46	0.47	0.48	0.49	0.50	0.51	0.52	0.54	0.56	0.54	0.53	0.52	0.50

TABLE 17

Schönrock's Table for Determining Water in Sugar Solutions by Means of the Abbe Refractometer

$N_D^{20^\circ}$	W	$N_D^{20^\circ}$	W	$N_D^{20^\circ}$	W	$N_D^{20^\circ}$	W	$N_D^{20^\circ}$	W
1.3330	100.0	1.3367	97.5	1.3403	95.0	1.3441	92.5	1.3479	90.0
1.3331	99.9	1.3368	97.4	1.3405	94.9	1.3442	92.4	1.3481	89.9
1.3333	99.8	1.3369	97.3	1.3406	94.8	1.3443	92.3	1.3482	89.9
1.3334	99.7	1.3371	97.2	1.3407	94.7	1.3445	92.2	1.3483	89.7
1.3336	99.6	1.3373	97.1	1.3409	94.6	1.3447	92.1	1.3485	89.6
1.3337	99.5	1.3374	97.0	1.3411	94.5	1.3448	92.0	1.3487	89.5
1.3338	99.4	1.3375	96.9	1.3412	94.4	1.3450	91.9	1.3488	89.4
1.3340	99.3	1.3377	96.8	1.3413	94.3	1.3451	91.8	1.3489	89.3
1.3341	99.2	1.3378	96.7	1.3415	94.2	1.3453	91.7	1.3491	89.2
1.3342	99.1	1.3380	96.6	1.3417	94.1	1.3454	91.6	1.3493	89.1
1.3344	99.0	1.3381	96.5	1.3418	94.0	1.3456	91.5	1.3494	89.0
1.3345	98.9	1.3382	96.4	1.3419	93.9	1.3458	91.4	1.3496	88.9
1.3347	98.8	1.3384	96.3	1.3421	93.8	1.3459	91.3	1.3497	88.8
1.3348	98.7	1.3385	96.2	1.3423	93.7	1.3461	91.2	1.3499	88.7
1.3350	98.6	1.3387	96.1	1.3424	93.6	1.3462	91.1	1.3500	88.6
1.3351	98.5	1.3388	96.0	1.3425	93.5	1.3464	91.0	1.3502	88.5
1.3353	98.4	1.3389	95.9	1.3427	93.4	1.3465	90.0	1.3504	88.4
1.3355	98.3	1.3391	95.8	1.3429	93.3	1.3467	90.8	1.3505	88.3
1.3356	98.2	1.3393	95.7	1.3430	93.2	1.3469	90.7	1.3507	88.2
1.3357	98.1	1.3394	95.6	1.3431	93.1	1.3470	90.6	1.3508	88.1
1.3359	98.0	1.3395	95.5	1.3433	93.0	1.3471	90.5	1.3510	88.0
1.3361	97.9	1.3397	95.4	1.3435	92.9	1.3473	90.4	1.3512	87.9
1.3362	97.8	1.3399	95.3	1.3436	92.8	1.3475	90.3	1.3513	87.8
1.3363	97.7	1.3400	95.2	1.3437	92.7	1.3476	90.2	1.3515	87.7
1.3365	97.6	1.3401	95.1	1.3439	92.6	1.3477	90.1	1.3516	87.6

TABLE 17—Continued

N_D^{20}	W	N_D^{20}	W	N_D^{20}	W	N_D^{20}	W	N_D^{20}	W
1.3518	87.5	1.3622	81.0	1.3731	74.5	1.3847	68.0	1.3968	61.5
1.3520	87.4	1.3624	80.9	1.3733	74.4	1.3849	67.9	1.3970	61.4
1.3521	87.3	1.3625	80.8	1.3735	74.3	1.3851	67.8	1.3972	61.3
1.3523	87.2	1.3627	80.7	1.3737	74.2	1.3852	67.7	1.3974	61.2
1.3524	87.1	1.3629	80.6	1.3738	74.1	1.3854	67.6	1.3976	61.1
1.3526	87.0	1.3631	80.5	1.3740	74.0	1.3856	67.5	1.3978	61.0
1.3527	86.9	1.3632	80.4	1.3742	73.9	1.3858	67.4	1.3980	60.9
1.3529	86.8	1.3634	80.3	1.3744	73.8	1.3860	67.3	1.3982	60.8
1.3531	86.7	1.3636	80.2	1.3745	73.7	1.3861	67.2	1.3984	60.7
1.3532	86.6	1.3637	80.1	1.3747	73.6	1.3863	67.1	1.3986	60.6
1.3533	86.5	1.3639	80.0	1.3749	73.5	1.3865	67.0	1.3987	60.5
1.3535	86.4	1.3641	79.9	1.3751	73.4	1.3867	66.9	1.3989	60.4
1.3537	86.3	1.3642	79.8	1.3753	73.3	1.3869	66.8	1.3991	60.3
1.3538	86.2	1.3644	79.7	1.3754	73.2	1.3870	66.7	1.3993	60.2
1.3539	86.1	1.3645	79.6	1.3756	73.1	1.3872	66.6	1.3995	60.1
1.3541	86.0	1.3647	79.5	1.3758	73.0	1.3874	66.5	1.3997	60.0
1.3543	85.9	1.3649	79.4	1.3760	72.9	1.3876	66.4	1.3999	59.9
1.3544	85.8	1.3650	79.3	1.3761	72.8	1.3878	66.3	1.4001	59.8
1.3546	85.7	1.3652	79.2	1.3763	72.7	1.3879	66.2	1.4003	59.7
1.3547	85.6	1.3653	79.1	1.3765	72.6	1.3881	66.1	1.4005	59.6
1.3549	85.5	1.3655	79.0	1.3767	72.5	1.3883	66.0	1.4007	59.5
1.3551	85.4	1.3657	78.9	1.3768	72.4	1.3885	65.9	1.4008	59.4
1.3552	85.3	1.3658	78.8	1.3770	72.3	1.3887	65.8	1.4010	59.3
1.3554	85.2	1.3660	78.7	1.3772	72.2	1.3889	65.7	1.4012	59.2
1.3555	85.1	1.3662	78.6	1.3773	72.1	1.3891	65.6	1.4014	59.1
1.3557	85.0	1.3663	78.5	1.3775	72.0	1.3893	65.5	1.4016	59.0
1.3559	84.9	1.3665	78.4	1.3777	71.9	1.3894	65.4	1.4018	58.9
1.3560	84.8	1.3667	78.3	1.3779	71.8	1.3896	65.3	1.4020	58.8
1.3562	84.7	1.3669	78.2	1.3780	71.7	1.3898	65.2	1.4022	58.7
1.3563	84.6	1.3670	78.1	1.3782	71.6	1.3900	65.1	1.4024	58.6
1.3565	84.5	1.3672	78.0	1.3784	71.5	1.3902	65.0	1.4026	58.5
1.3567	84.4	1.3674	77.9	1.3786	71.4	1.3904	64.9	1.4028	58.4
1.3568	84.3	1.3675	77.8	1.3788	71.3	1.3906	64.8	1.4030	58.3
1.3570	84.2	1.3677	77.7	1.3789	71.2	1.3907	64.7	1.4032	58.2
1.3571	84.1	1.3679	77.6	1.3791	71.1	1.3909	64.6	1.4034	58.1
1.3573	84.0	1.3681	77.5	1.3793	71.0	1.3911	64.5	1.4036	58.0
1.3575	83.9	1.3682	77.4	1.3795	70.9	1.3913	64.4	1.4038	57.9
1.3576	83.8	1.3684	77.3	1.3797	70.8	1.3915	64.3	1.4040	57.8
1.3578	83.7	1.3686	77.2	1.3798	70.7	1.3916	64.2	1.4042	57.7
1.3580	83.6	1.3687	77.1	1.3800	70.6	1.3918	64.1	1.4044	57.6
1.3582	83.5	1.3689	77.0	1.3802	70.5	1.3920	64.0	1.4046	57.5
1.3583	83.4	1.3691	76.9	1.3804	70.4	1.3922	63.9	1.4048	57.4
1.3585	83.3	1.3692	76.8	1.3806	70.3	1.3924	63.8	1.4050	57.3
1.3587	83.2	1.3694	76.7	1.3807	70.2	1.3926	63.7	1.4052	57.2
1.3588	83.1	1.3696	76.6	1.3809	70.1	1.3928	63.6	1.4054	57.1
1.3590	83.0	1.3698	76.5	1.3811	70.0	1.3929	63.5	1.4056	57.0
1.3592	82.9	1.3699	76.4	1.3813	69.9	1.3931	63.4	1.4058	56.9
1.3593	82.8	1.3701	76.3	1.3815	69.8	1.3933	63.3	1.4060	56.8
1.3595	82.7	1.3703	76.2	1.3816	69.7	1.3935	63.2	1.4062	56.7
1.3596	82.6	1.3704	76.1	1.3818	69.6	1.3937	63.1	1.4064	56.6
1.3598	82.5	1.3706	76.0	1.3820	69.5	1.3939	63.0	1.4066	56.5
1.3600	82.4	1.3708	75.9	1.3822	69.4	1.3941	62.9	1.4068	56.4
1.3601	82.3	1.3709	75.8	1.3824	69.3	1.3943	62.8	1.4070	56.3
1.3603	82.2	1.3711	75.7	1.3825	69.2	1.3945	62.7	1.4072	56.2
1.3604	82.1	1.3713	75.6	1.3827	69.1	1.3947	62.6	1.4074	56.1
1.3606	82.0	1.3715	75.5	1.3829	69.0	1.3949	62.5	1.4076	56.0
1.3608	81.9	1.3716	75.4	1.3831	68.9	1.3950	62.4	1.4078	55.9
1.3609	81.8	1.3718	75.3	1.3833	68.8	1.3952	62.3	1.4080	55.8
1.3611	81.7	1.3720	75.2	1.3834	68.7	1.3954	62.2	1.4082	55.7
1.3612	81.6	1.3721	75.1	1.3836	68.6	1.3956	62.1	1.4084	55.6
1.3614	81.5	1.3723	75.0	1.3838	68.5	1.3958	62.0	1.4086	55.5
1.3616	81.4	1.3725	74.9	1.3840	68.4	1.3960	61.9	1.4088	55.4
1.3617	81.3	1.3726	74.8	1.3842	68.3	1.3962	61.8	1.4090	55.3
1.3619	81.2	1.3728	74.7	1.3843	68.2	1.3964	61.7	1.4092	55.2
1.3620	81.1	1.3730	74.6	1.3845	68.1	1.3966	61.6	1.4094	55.1

TABLE 17—Continued

$N_D^{20^\circ}$	W	$N_D^{20^\circ}$	W	$N_D^{20^\circ}$	W	$N_D^{20^\circ}$	W	$N_D^{20^\circ}$	W
1.4096	55.0	1.4221	49.0	1.4351	43.0	1.4486	37.0	1.4625	31.1
1.4098	54.9	1.4223	48.9	1.4353	42.9	1.4488	36.9	1.4628	31.0
1.4100	54.8	1.4225	48.8	1.4355	42.8	1.4491	36.8	1.4630	30.9
1.4102	54.7	1.4227	48.7	1.4358	42.7	1.4493	36.7	1.4632	30.8
1.4104	54.6	1.4229	48.6	1.4360	42.6	1.4495	36.6	1.4635	30.7
1.4107	54.5	1.4231	48.5	1.4362	42.5	1.4497	36.5	1.4637	30.6
1.4109	54.4	1.4234	48.4	1.4364	42.4	1.4500	36.4	1.4639	30.5
1.4111	54.3	1.4236	48.3	1.4366	42.3	1.4502	36.3	1.4642	30.4
1.4113	54.2	1.4238	48.2	1.4369	42.2	1.4504	36.2	1.4644	30.3
1.4115	54.1	1.4240	48.1	1.4371	42.1	1.4507	36.1	1.4646	30.2
1.4117	54.0	1.4242	48.0	1.4373	42.0	1.4509	36.0	1.4649	30.1
1.4119	53.9	1.4244	47.9	1.4375	41.9	1.4511	35.9	1.4651	30.0
1.4121	53.8	1.4246	47.8	1.4378	41.8	1.4514	35.8	1.4653	29.9
1.4123	53.7	1.4249	47.7	1.4380	41.7	1.4516	35.7	1.4656	29.8
1.4125	53.6	1.4251	47.6	1.4382	41.6	1.4518	35.6	1.4658	29.7
1.4127	53.5	1.4253	47.5	1.4385	41.5	1.4521	35.5	1.4661	29.6
1.4129	53.4	1.4255	47.4	1.4387	41.4	1.4523	35.4	1.4663	29.5
1.4131	53.3	1.4257	47.3	1.4389	41.3	1.4525	35.3	1.4666	29.4
1.4133	53.2	1.4260	47.2	1.4391	41.2	1.4527	35.2	1.4668	29.3
1.4135	53.1	1.4262	47.1	1.4394	41.1	1.4530	35.1	1.4671	29.2
1.4137	53.0	1.4264	47.0	1.4396	41.0	1.4532	35.0	1.4673	29.1
1.4139	52.9	1.4266	46.9	1.4398	40.9	1.4534	34.9	1.4676	29.0
1.4141	52.8	1.4268	46.8	1.4400	40.8	1.4537	34.8	1.4678	28.9
1.4143	52.7	1.4270	46.7	1.4403	40.7	1.4539	34.7	1.4681	28.8
1.4145	52.6	1.4272	46.6	1.4405	40.6	1.4541	34.6	1.4683	28.7
1.4147	52.5	1.4275	46.5	1.4407	40.5	1.4544	34.5	1.4685	28.6
1.4150	52.4	1.4277	46.4	1.4409	40.4	1.4546	34.4	1.4688	28.5
1.4152	52.3	1.4279	46.3	1.4411	40.3	1.4548	34.3	1.4690	28.4
1.4154	52.2	1.4281	46.2	1.4414	40.2	1.4550	34.2	1.4693	28.3
1.4156	52.1	1.4283	46.1	1.4416	40.1	1.4553	34.1	1.4695	28.2
1.4158	52.0	1.4285	46.0	1.4418	40.0	1.4555	34.0	1.4698	28.1
1.4160	51.9	1.4287	45.9	1.4420	39.9	1.4558	33.9	1.4700	28.0
1.4162	51.8	1.4289	45.8	1.4423	39.8	1.4561	33.9	1.4703	27.9
1.4164	51.7	1.4292	45.7	1.4425	39.7	1.4563	33.8	1.4705	27.8
1.4166	51.6	1.4294	45.6	1.4427	39.6	1.4565	33.7	1.4708	27.7
1.4169	51.5	1.4296	45.5	1.4429	39.5	1.4567	33.6	1.4710	27.6
1.4171	51.4	1.4298	45.4	1.4432	39.4	1.4570	33.5	1.4713	27.5
1.4173	51.3	1.4300	45.3	1.4434	39.3	1.4572	33.4	1.4715	27.4
1.4175	51.2	1.4303	45.2	1.4436	39.2	1.4574	33.3	1.4717	27.3
1.4177	51.1	1.4305	45.1	1.4439	39.1	1.4577	33.2	1.4720	27.2
1.4179	51.0	1.4307	45.0	1.4441	39.0	1.4579	33.1	1.4722	27.1
1.4181	50.9	1.4309	44.9	1.4443	38.9	1.4581	33.0	1.4725	27.0
1.4183	50.8	1.4311	44.8	1.4446	38.8	1.4584	32.9	1.4727	26.9
1.4185	50.7	1.4313	44.7	1.4448	38.7	1.4586	32.8	1.4730	26.8
1.4187	50.6	1.4316	44.6	1.4450	38.6	1.4588	32.7	1.4732	26.7
1.4189	50.5	1.4318	44.5	1.4453	38.5	1.4591	32.6	1.4735	26.6
1.4192	50.4	1.4320	44.4	1.4455	38.4	1.4593	32.5	1.4737	26.5
1.4194	50.3	1.4322	44.3	1.4457	38.3	1.4595	32.4	1.4740	26.4
1.4196	50.2	1.4325	44.2	1.4459	38.2	1.4598	32.3	1.4742	26.3
1.4198	50.1	1.4327	44.1	1.4462	38.1	1.4600	32.2	1.4744	26.2
1.4200	50.0	1.4329	44.0	1.4464	38.0	1.4602	32.1	1.4747	26.1
1.4202	49.9	1.4331	43.9	1.4466	37.9	1.4605	32.0	1.4749	26.0
1.4204	49.8	1.4333	43.8	1.4468	37.8	1.4607	31.9	1.4752	25.9
1.4206	49.7	1.4336	43.7	1.4471	37.7	1.4609	31.8	1.4754	25.8
1.4208	49.6	1.4338	43.6	1.4473	37.6	1.4612	31.7	1.4757	25.7
1.4211	49.5	1.4340	43.5	1.4475	37.5	1.4614	31.6	1.4759	25.6
1.4213	49.4	1.4342	43.4	1.4477	37.4	1.4616	31.5	1.4762	25.5
1.4215	49.3	1.4344	43.3	1.4479	37.3	1.4619	31.4	1.4764	25.4
1.4217	49.2	1.4347	43.2	1.4482	37.2	1.4621	31.3	1.4767	25.3
1.4219	49.1	1.4349	43.1	1.4484	37.1	1.4623	31.2	1.4769	25.3

⁶⁹ The values of the refractive index from 34 per cent to 15 per cent are taken from Main's table (Int. Sugar Jour., 9, p. 481).

TABLE 17—Continued

$N_D^{20^\circ}$	W	$N_D^{20^\circ}$	W	$N_D^{20^\circ}$	W	$N_D^{20^\circ}$	W	$N_D^{20^\circ}$	W
1.4772	25.1	1.4822	23.1	1.4873	21.1	1.4925	19.1	1.4978	17.1
1.4774	25.0	1.4825	23.0	1.4876	21.0	1.4927	19.0	1.4980	17.0
1.4777	24.9	1.4827	22.9	1.4878	20.9	1.4930	18.9	1.4983	16.9
1.4779	24.8	1.4830	22.8	1.4881	20.8	1.4933	18.8	1.4985	16.8
1.4782	24.7	1.4832	22.7	1.4883	20.7	1.4935	18.7	1.4988	16.7
1.4784	24.6	1.4835	22.6	1.4886	20.6	1.4938	18.6	1.4991	16.6
1.4787	24.5	1.4838	22.5	1.4888	20.5	1.4941	18.5	1.4993	16.5
1.4789	24.4	1.4840	22.4	1.4891	20.4	1.4943	18.4	1.4996	16.4
1.4792	24.3	1.4843	22.3	1.4893	20.3	1.4946	18.3	1.4999	16.3
1.4794	24.2	1.4845	22.2	1.4896	20.2	1.4949	18.2	1.5001	16.2
1.4797	24.1	1.4848	22.1	1.4898	20.1	1.4951	18.1	1.5004	16.1
1.4799	24.0	1.4850	22.0	1.4901	20.0	1.4954	18.0	1.5007	16.0
1.4802	23.9	1.4853	21.9	1.4904	19.9	1.4956	17.9	1.5009	15.9
1.4804	23.8	1.4855	21.8	1.4906	19.8	1.4959	17.8	1.5012	15.8
1.4807	23.7	1.4858	21.7	1.4909	19.7	1.4962	17.7	1.5015	15.7
1.4810	23.6	1.4860	21.6	1.4912	19.6	1.4964	17.6	1.5017	15.6
1.4812	23.5	1.4863	21.5	1.4914	19.5	1.4967	17.5	1.5020	15.5
1.4815	23.4	1.4865	21.4	1.4917	19.4	1.4970	17.4	1.5022	15.4
1.4817	23.3	1.4868	21.3	1.4919	19.3	1.4972	17.3	1.5025	15.3
1.4820	23.2	1.4871	21.2	1.4922	19.2	1.4975	17.2	1.5028	15.2
								1.5030	15.1
								1.5033	15.0

TABLE 18

Stanek's Correction Table for Determining Water in Sugar Solutions by Means of the Abbe Refractometer when Readings are Made at Other Temperatures than 20° C

Water, per cent	95	90	85	80	70	60	50	40	30	25	Water, per cent
Temperature °C	To be added to the per cent of water										Temperature °C
15	0.25	0.27	0.31	0.31	0.34	0.35	0.36	0.37	0.36	0.36	15
16	0.21	0.23	0.26	0.27	0.29	0.31	0.31	0.32	0.31	0.29	16
17	0.16	0.18	0.20	0.20	0.22	0.23	0.23	0.23	0.20	0.17	17
18	0.11	0.12	0.14	0.14	0.15	0.16	0.16	0.15	0.12	0.09	18
19	0.06	0.07	0.08	0.08	0.08	0.09	0.09	0.08	0.07	0.05	19
Temperature °C	To be subtracted from the per cent of water										Temperature °C
21	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	21
22	0.12	0.14	0.14	0.14	0.14	0.14	0.15	0.14	0.14	0.14	22
23	0.18	0.20	0.20	0.21	0.21	0.21	0.23	0.21	0.22	0.22	23
24	0.24	0.26	0.26	0.27	0.28	0.28	0.30	0.28	0.29	0.29	24
25	0.30	0.32	0.32	0.34	0.36	0.36	0.38	0.36	0.36	0.37	25
26	0.36	0.39	0.39	0.41	0.43	0.43	0.46	0.44	0.43	0.44	26
27	0.43	0.46	0.46	0.48	0.50	0.51	0.55	0.62	0.50	0.51	27
28	0.50	0.53	0.53	0.55	0.58	0.59	0.63	0.70	0.57	0.59	28
29	0.57	0.60	0.61	0.62	0.66	0.67	0.71	0.78	0.65	0.67	29
30	0.64	0.67	0.70	0.71	0.74	0.75	0.80	0.86	0.73	0.75	30
Water, per cent	95	90	85	80	70	60	50	40	30	25	Water, per cent

TABLE 19

Density⁷⁰ of Solutions of Cane Sugar at 20° C

[This table is the basis for standardizing hydrometers indicating per cent of sugar at 20° C]

Per cent sugar	Tenths of per cent									
	0	1	2	3	4	5	6	7	8	9
0	0.998234	0.998622	0.999010	0.999398	0.999786	1.000174	1.000563	1.000952	1.001342	1.001731
1	1.002120	1.002509	1.002897	1.003286	1.003675	1.004064	1.004453	1.004844	1.005234	1.005624
2	1.006015	1.006405	1.006796	1.007188	1.007580	1.007972	1.008363	1.008755	1.009148	1.009541
3	1.009934	1.010327	1.010721	1.011115	1.011510	1.011904	1.012298	1.012694	1.013089	1.013485
4	1.013881	1.014277	1.014673	1.015070	1.015467	1.015864	1.016261	1.016659	1.017058	1.017456
5	1.017854	1.018253	1.018652	1.019052	1.019451	1.019851	1.020251	1.020651	1.021053	1.021454
6	1.021855	1.022257	1.022659	1.023061	1.023463	1.023867	1.024270	1.024673	1.025077	1.025481
7	1.025885	1.026289	1.026694	1.027099	1.027504	1.027910	1.028316	1.028722	1.029128	1.029535
8	1.029942	1.030349	1.030757	1.031165	1.031573	1.031982	1.032391	1.032800	1.033209	1.033619
9	1.034029	1.034439	1.034850	1.035260	1.035671	1.036082	1.036494	1.036906	1.037318	1.037730
10	1.038143	1.038556	1.038970	1.039383	1.039797	1.040212	1.040626	1.041041	1.041456	1.041872
11	1.042288	1.042704	1.043121	1.043537	1.043954	1.044370	1.044788	1.045206	1.045625	1.046043
12	1.046462	1.046881	1.047300	1.047720	1.048140	1.048559	1.048980	1.049401	1.049822	1.050243
13	1.050665	1.051087	1.051510	1.051933	1.052356	1.052778	1.053202	1.053626	1.054050	1.054475
14	1.054900	1.055325	1.055751	1.056176	1.056602	1.057029	1.057455	1.057882	1.058310	1.058737
15	1.059165	1.059593	1.060022	1.060451	1.060880	1.061308	1.061738	1.062168	1.062598	1.063029
16	1.063460	1.063892	1.064324	1.064756	1.065188	1.065621	1.066054	1.066487	1.066921	1.067355
17	1.067789	1.068223	1.068658	1.069093	1.069529	1.069964	1.070400	1.070836	1.071273	1.071710
18	1.072147	1.072585	1.073023	1.073461	1.073900	1.074338	1.074777	1.075217	1.075657	1.076097
19	1.076537	1.076978	1.077419	1.077860	1.078302	1.078744	1.079187	1.079629	1.080072	1.080515
20	1.080959	1.081403	1.081848	1.082292	1.082737	1.083182	1.083628	1.084074	1.084520	1.084967
21	1.085414	1.085861	1.086309	1.086757	1.087205	1.087652	1.088101	1.088550	1.089000	1.089450
22	1.089900	1.090351	1.090802	1.091253	1.091704	1.092155	1.092607	1.093060	1.093513	1.093966
23	1.094420	1.094874	1.095328	1.095783	1.096236	1.096691	1.097147	1.097603	1.098058	1.098514
24	1.098971	1.099428	1.099886	1.100344	1.100802	1.101259	1.101718	1.102177	1.102637	1.103097
25	1.103557	1.104017	1.104478	1.104938	1.105400	1.105862	1.106324	1.106786	1.107248	1.107711
26	1.108175	1.108639	1.109103	1.109568	1.110033	1.110499	1.110963	1.111429	1.111895	1.112361
27	1.112828	1.113295	1.113763	1.114232	1.114697	1.115166	1.115635	1.116104	1.116572	1.117042
28	1.117512	1.117982	1.118453	1.118923	1.119395	1.119867	1.120339	1.120812	1.121284	1.121757
29	1.122231	1.122705	1.123179	1.123653	1.124128	1.124603	1.125079	1.125555	1.126030	1.126507
30	1.126984	1.127461	1.127939	1.128417	1.128896	1.129374	1.129853	1.130332	1.130812	1.131292
31	1.131773	1.132254	1.132735	1.133216	1.133698	1.134180	1.134663	1.135146	1.135628	1.136112
32	1.136596	1.137080	1.137565	1.138049	1.138534	1.139020	1.139506	1.139993	1.140479	1.140966
33	1.141453	1.141941	1.142429	1.142916	1.143405	1.143894	1.144384	1.144874	1.145365	1.145854
34	1.146345	1.146836	1.147328	1.147820	1.148313	1.148805	1.149298	1.149792	1.150286	1.150780
35	1.151275	1.151770	1.152265	1.152760	1.153256	1.153752	1.154249	1.154746	1.155242	1.155740
36	1.156238	1.156736	1.157235	1.157733	1.158232	1.158733	1.159233	1.159733	1.160233	1.160734
37	1.161236	1.161738	1.162240	1.162742	1.163245	1.163748	1.164252	1.164756	1.165259	1.165764
38	1.166269	1.166775	1.167281	1.167786	1.168293	1.168800	1.169307	1.169815	1.170322	1.170831
39	1.171340	1.171849	1.172359	1.172869	1.173379	1.173889	1.174400	1.174911	1.175423	1.175935
40	1.176447	1.176960	1.177473	1.177987	1.178501	1.179014	1.179527	1.180044	1.180560	1.181076
41	1.181592	1.182108	1.182625	1.183142	1.183660	1.184178	1.184696	1.185215	1.185734	1.186253
42	1.186773	1.187293	1.187814	1.188335	1.188856	1.189377	1.189899	1.190423	1.190946	1.191469
43	1.191993	1.192517	1.193041	1.193565	1.194090	1.194616	1.195141	1.195667	1.196193	1.196720
44	1.197247	1.197775	1.198303	1.198832	1.199360	1.199890	1.200420	1.200950	1.201480	1.202010
45	1.202540	1.203071	1.203603	1.204136	1.204668	1.205200	1.205733	1.206266	1.206801	1.207335
46	1.207870	1.208405	1.208940	1.209477	1.210013	1.210549	1.211086	1.211623	1.212162	1.212700
47	1.213238	1.213777	1.214317	1.214856	1.215395	1.215935	1.216476	1.217017	1.217559	1.218101
48	1.218643	1.219185	1.219729	1.220272	1.220815	1.221360	1.221904	1.222449	1.222995	1.223540
49	1.224086	1.224632	1.225180	1.225727	1.226274	1.226823	1.227371	1.227919	1.228469	1.229018
50	1.229567	1.230117	1.230668	1.231219	1.231770	1.232322	1.232874	1.233426	1.233979	1.234532
51	1.235085	1.235639	1.236194	1.236748	1.237303	1.237859	1.238414	1.238970	1.239527	1.240084
52	1.240641	1.241198	1.241757	1.242315	1.242873	1.243433	1.243992	1.244552	1.245113	1.245673
53	1.246234	1.246795	1.247358	1.247920	1.248482	1.249046	1.249610	1.250172	1.250737	1.251301
54	1.251866	1.252431	1.252997	1.253563	1.254129	1.254697	1.255264	1.255831	1.256400	1.256967

⁷⁰ According to Dr. F. Plato (Kaiserlichen Normal-Eichungs-Kommission, Wiss. Abh., 2, p. 153; 1900).

TABLE 21

Munson and Walker's Table for Calculating Dextrose, Invert Sugar Alone, Invert Sugar in the Presence of Sucrose (0.4 Gram and 2 Grams Total Sugar), Lactose, Lactose and Sucrose (2 Mixtures) and Maltose (Crystallized).

[Expressed in milligrams]

Cuprous oxid (Cu_2O)	Copper (Cu)	Dex- trose (d -glu- cose)	Invert sugar	Invert sugar and sucrose		Lactose	Lactose and sucrose		Maltose	Cu- prous oxid (Cu_2O)
				0.4 gram total sugar	2 grams total sugar	$\text{C}_{12}\text{H}_{22}\text{O}_{11}$ + H_2O	1 lactose, 4 sucrose	1 lactose, 12 sucrose	$\text{C}_{12}\text{H}_{22}\text{O}_{11}$ + H_2O	
10	8.9	4.0	4.5	1.6	-----	6.3	6.1	-----	6.2	10
11	9.8	4.5	5.0	2.1	-----	6.9	6.7	-----	7.0	11
12	10.7	4.9	5.4	2.5	-----	7.5	7.3	-----	7.9	12
13	11.5	5.3	5.8	3.0	-----	8.2	7.9	-----	8.7	13
14	12.4	5.7	6.3	3.4	-----	8.8	8.5	-----	9.5	14
15	13.3	6.2	6.7	3.9	-----	9.4	9.1	-----	10.4	15
16	14.2	6.6	7.2	4.3	-----	10.0	9.7	-----	11.2	16
17	15.1	7.0	7.6	4.8	-----	10.7	10.3	-----	12.0	17
18	16.0	7.5	8.1	5.2	-----	11.3	10.9	-----	12.9	18
19	16.9	7.9	8.5	5.7	-----	11.9	11.5	-----	13.7	19
20	17.8	8.3	8.9	6.1	-----	12.5	12.1	-----	14.6	20
21	18.7	8.7	9.4	6.6	-----	13.2	12.7	-----	15.4	21
22	19.5	9.2	9.8	7.0	-----	13.8	13.3	-----	16.2	22
23	20.4	9.6	10.3	7.5	-----	14.4	13.9	-----	17.1	23
24	21.3	10.0	10.7	7.9	-----	15.0	14.5	-----	17.9	24
25	22.2	10.5	11.2	8.4	-----	15.7	15.2	-----	18.7	25
26	23.1	10.9	11.6	8.8	-----	16.3	15.8	-----	19.6	26
27	24.0	11.3	12.0	9.3	-----	16.9	16.4	-----	20.4	27
28	24.9	11.8	12.5	9.7	-----	17.6	17.0	-----	21.2	28
29	25.8	12.2	12.9	10.2	-----	18.2	17.6	-----	22.1	29
30	26.6	12.6	13.4	10.7	4.3	18.8	18.2	-----	22.9	30
31	27.5	13.1	13.8	11.1	4.7	19.4	18.8	-----	23.7	31
32	28.4	13.5	14.3	11.6	5.2	20.1	19.4	-----	24.6	32
33	29.3	13.9	14.7	12.0	5.6	20.7	20.0	-----	25.4	33
34	30.2	14.3	15.2	12.5	6.1	21.4	20.7	-----	26.2	34
35	31.1	14.8	15.6	12.9	6.5	22.1	21.3	-----	27.1	35
36	32.0	15.2	16.1	13.4	7.0	22.8	22.0	-----	27.9	36
37	32.9	15.6	16.5	13.8	7.4	23.5	22.7	-----	28.7	37
38	33.8	16.1	16.9	14.3	7.9	24.2	23.3	-----	29.6	38
39	34.6	16.5	17.4	14.7	8.4	24.8	24.0	-----	30.4	39
40	35.5	16.9	17.8	15.2	8.8	25.5	24.7	-----	31.3	40
41	36.4	17.4	18.3	15.6	9.3	26.2	25.3	-----	32.1	41
42	37.3	17.8	18.7	16.1	9.7	26.9	26.0	-----	32.9	42
43	38.2	18.2	19.2	16.6	10.2	27.6	26.6	-----	33.8	43
44	39.1	18.7	19.6	17.0	10.7	28.3	27.3	-----	34.6	44
45	40.0	19.1	20.1	17.5	11.1	28.9	28.0	-----	35.4	45
46	40.9	19.6	20.5	17.9	11.6	29.6	28.6	-----	36.3	46
47	41.7	20.0	21.0	18.4	12.0	30.3	29.3	-----	37.1	47
48	42.6	20.4	21.4	18.8	12.5	31.0	30.0	-----	37.9	48
49	43.5	20.9	21.9	19.3	12.9	31.7	30.6	-----	38.8	49
50	44.4	21.3	22.3	19.7	13.4	32.3	31.3	-----	39.6	50
51	45.3	21.7	22.8	20.2	13.9	33.0	32.0	-----	40.4	51
52	46.2	22.2	23.2	20.7	14.3	33.7	32.6	-----	41.3	52
53	47.1	22.6	23.7	21.1	14.8	34.4	33.3	-----	42.1	53
54	48.0	23.0	24.1	21.6	15.2	35.1	34.0	-----	42.9	54
55	48.9	23.5	24.6	22.0	15.7	35.8	34.6	-----	43.8	55
56	49.7	23.9	25.0	22.5	16.2	36.4	35.3	-----	44.6	56
57	50.6	24.3	25.5	22.9	16.6	37.1	35.9	-----	45.4	57
58	51.5	24.8	25.9	23.4	17.1	37.8	36.6	-----	46.3	58
59	52.4	25.2	26.4	23.9	17.5	38.5	37.3	-----	47.1	59

TABLE 21—Continued

Cuprous oxid (Cu ₂ O)	Copper (Cu)	Dex- trose (d-glu- cose)	Invert sugar	Invert sugar and sucrose		Lactose C ₁₂ H ₂₂ O ₁₁ +H ₂ O	Lactose and sucrose		Maltose C ₁₂ H ₂₂ O ₁₁ +H ₂ O	Cu- prous oxid (Cu ₂ O)
				0.4 gram total sugar	2 grams total sugar		1 lactose, 4 sucrose	1 lactose, 12 sucrose		
60	53.3	25.6	26.8	24.3	18.0	39.2	37.9	.....	48.0	60
61	54.2	26.1	27.3	24.8	18.5	39.9	38.6	.....	48.8	61
62	55.1	26.5	27.7	25.2	18.9	40.5	39.3	.....	49.6	62
63	56.0	27.0	28.2	25.7	19.4	41.2	39.9	.....	50.5	63
64	56.8	27.4	28.6	26.2	19.8	41.9	40.6	.....	51.3	64
65	57.7	27.8	29.1	26.6	20.3	42.6	41.3	.....	52.1	65
66	58.6	28.3	29.5	27.1	20.8	43.3	41.9	.....	53.0	66
67	59.5	28.7	30.0	27.5	21.2	44.0	42.6	40.1	53.8	67
68	60.4	29.2	30.4	28.0	21.7	44.7	43.3	40.7	54.6	68
69	61.3	29.6	30.9	28.5	22.2	45.3	43.9	41.3	55.5	69
70	62.2	30.0	31.3	28.9	22.6	46.0	44.6	41.9	56.3	70
71	63.1	30.5	31.8	29.4	23.1	46.7	45.3	42.5	57.1	71
72	64.0	30.9	32.3	29.8	23.5	47.4	45.9	43.1	58.0	72
73	64.8	31.4	32.7	30.3	24.0	48.1	46.6	43.7	58.8	73
74	65.7	31.8	33.2	30.8	24.5	48.8	47.3	44.2	59.6	74
75	66.6	32.2	33.6	31.2	24.9	49.4	47.9	44.8	60.5	75
76	67.5	32.7	34.1	31.7	25.4	50.1	48.6	45.4	61.3	76
77	68.4	33.1	34.5	32.1	25.9	50.8	49.3	46.0	62.1	77
78	69.3	33.6	35.0	32.6	26.3	51.5	49.9	46.6	63.0	78
79	70.2	34.0	35.4	33.1	26.8	52.2	50.6	47.2	63.8	79
80	71.1	34.4	35.9	33.5	27.3	52.9	51.3	47.8	64.6	80
81	71.9	34.9	36.3	34.0	27.7	53.6	51.9	48.4	65.5	81
82	72.8	35.3	36.8	34.5	28.2	54.2	52.6	49.0	66.3	82
83	73.7	35.8	37.3	34.9	28.6	54.9	53.3	49.6	67.1	83
84	74.6	36.2	37.7	35.4	29.1	55.6	53.9	50.1	68.0	84
85	75.5	36.7	38.2	35.8	29.6	56.3	54.6	50.7	68.8	85
86	76.4	37.1	38.6	36.3	30.0	57.0	55.3	51.3	69.7	86
87	77.3	37.5	39.1	36.8	30.5	57.7	55.9	51.9	70.5	87
88	78.2	38.0	39.5	37.2	31.0	58.4	56.6	52.5	71.3	88
89	79.1	38.4	40.0	37.7	31.4	59.0	57.3	53.1	72.2	89
90	79.9	38.9	40.4	38.2	31.9	59.7	57.9	53.7	73.0	90
91	80.8	39.3	40.9	38.6	32.4	60.4	58.6	54.3	73.8	91
92	81.7	39.8	41.4	39.1	32.8	61.1	59.3	54.9	74.7	92
93	82.6	40.2	41.8	39.6	33.3	61.8	59.9	55.5	75.5	93
94	83.5	40.6	42.3	40.0	33.8	62.5	60.6	56.0	76.3	94
95	84.4	41.1	42.7	40.5	34.2	63.2	61.3	56.6	77.2	95
96	85.3	41.5	43.2	41.0	34.7	63.8	61.9	57.2	78.0	96
97	86.2	42.0	43.7	41.4	35.2	64.5	62.6	57.8	78.8	97
98	87.1	42.4	44.1	41.9	35.6	65.2	63.3	58.4	79.7	98
99	87.9	42.9	44.6	42.4	36.1	65.9	63.9	59.0	80.5	99
100	88.8	43.3	45.0	42.8	36.6	66.6	64.6	59.6	81.3	100
101	89.7	43.8	45.5	43.3	37.0	67.3	65.3	60.2	82.2	101
102	90.6	44.2	46.0	43.8	37.5	68.0	66.0	60.8	83.0	102
103	91.5	44.7	46.4	44.2	38.0	68.7	66.6	61.4	83.8	103
104	92.4	45.1	46.9	44.7	38.5	69.3	67.3	62.0	84.7	104
105	93.3	45.5	47.3	45.2	38.9	70.0	68.0	62.6	85.5	105
106	94.2	46.0	47.8	45.6	39.4	70.7	68.6	63.2	86.3	106
107	95.0	46.4	48.3	46.1	39.9	71.4	69.3	63.8	87.2	107
108	95.9	46.9	48.7	46.6	40.3	72.1	70.0	64.4	88.0	108
109	96.8	47.3	49.2	47.0	40.8	72.8	70.6	65.0	88.8	109
110	97.7	47.8	49.6	47.5	41.3	73.5	71.3	65.6	89.7	110
111	98.6	48.2	50.1	48.0	41.7	74.2	72.0	66.1	90.5	111
112	99.5	48.7	50.6	48.4	42.2	74.8	72.6	66.7	91.3	112
113	100.4	49.1	51.0	48.9	42.7	75.5	73.3	67.3	92.2	113
114	101.3	49.6	51.5	49.4	43.2	76.2	74.0	67.9	93.0	114
115	102.2	50.0	51.9	49.8	43.6	76.9	74.6	68.5	93.9	115
116	103.0	50.5	52.4	50.3	44.1	77.6	75.3	69.1	94.7	116
117	103.9	50.9	52.9	50.8	44.6	78.3	76.0	69.7	95.5	117
118	104.8	51.4	53.3	51.2	45.0	79.0	76.7	70.3	96.4	118
119	105.7	51.8	53.8	51.7	45.5	79.6	77.3	70.9	97.2	119

TABLE 21—Continued

Cuprous oxid (Cu ₂ O)	Copper (Cu)	Dex- trose (d-glucose)	Invert sugar	Invert sugar and sucrose		Lactose C ₁₂ H ₂₂ O ₁₁ + H ₂ O	Lactose and sucrose		Maltose C ₁₂ H ₂₂ O ₁₁ + H ₂ O	Cu- prous oxid (Cu ₂ O)
				0.4 gram total sugar	2 grams total sugar		1 lactose, 4 sucrose	1 lactose, 12 sucrose		
120	106.6	52.3	54.3	52.2	46.0	80.3	78.0	71.5	98.0	120
121	107.5	52.7	54.7	52.7	46.5	81.0	78.7	72.1	98.9	121
122	108.4	53.2	55.2	53.1	46.9	81.7	79.3	72.7	99.7	122
123	109.3	53.6	55.7	53.6	47.4	82.4	80.0	73.3	100.5	123
124	110.1	54.1	56.1	54.1	47.9	83.1	80.7	73.9	101.4	124
125	111.0	54.5	56.6	54.5	48.3	83.8	81.3	74.5	102.2	125
126	111.9	55.0	57.0	55.0	48.8	84.5	82.0	75.1	103.0	126
127	112.8	55.4	57.5	55.5	49.3	85.1	82.7	75.7	103.9	127
128	113.7	55.9	58.0	55.9	49.8	85.8	83.4	76.3	104.7	128
129	114.6	56.3	58.4	56.4	50.2	86.5	84.0	76.9	105.5	129
130	115.5	56.8	58.9	56.9	50.7	87.2	84.7	77.5	106.4	130
131	116.4	57.2	59.4	57.4	51.2	87.9	85.4	78.1	107.2	131
132	117.3	57.7	59.8	57.8	51.7	88.6	86.0	78.7	108.0	132
133	118.1	58.1	60.3	58.3	52.1	89.3	86.7	79.3	108.9	133
134	119.0	58.6	60.8	58.8	52.6	90.0	87.4	79.7	109.7	134
135	119.9	59.0	61.2	59.3	53.1	90.6	88.1	80.5	110.5	135
136	120.8	59.5	61.7	59.7	53.6	91.3	88.7	81.1	111.4	136
137	121.7	60.0	62.2	60.2	54.0	92.0	89.4	81.7	112.2	137
138	122.6	60.4	62.6	60.7	54.5	92.7	90.1	82.3	113.0	138
139	123.5	60.9	63.1	61.2	55.0	93.4	90.7	82.9	113.9	139
140	124.4	61.3	63.6	61.6	55.5	94.1	91.4	83.5	114.7	140
141	125.2	61.8	64.0	62.1	55.9	94.8	92.1	84.1	115.5	141
142	126.1	62.2	64.5	62.6	56.4	95.5	92.8	84.7	116.4	142
143	127.0	62.7	65.0	63.1	56.9	96.1	93.4	85.3	117.2	143
144	127.9	63.1	65.4	63.5	57.4	96.8	94.1	85.9	118.0	144
145	128.8	63.6	65.9	64.0	57.8	97.5	94.8	86.5	118.9	145
146	129.7	64.0	66.4	64.5	58.3	98.2	95.4	87.1	119.7	146
147	130.6	64.5	66.9	65.0	58.8	98.9	96.1	87.7	120.5	147
148	131.5	65.0	67.3	65.4	59.3	99.6	96.8	88.3	121.4	148
149	132.4	65.4	67.8	65.9	59.7	100.3	97.5	88.9	122.2	149
150	133.2	65.9	68.3	66.4	60.2	101.0	98.1	89.5	123.0	150
151	134.1	66.3	68.7	66.9	60.7	101.6	98.8	90.2	123.9	151
152	135.0	66.8	69.2	67.3	61.2	102.3	99.5	90.8	124.7	152
153	135.9	67.2	69.7	67.8	61.7	103.0	100.1	91.4	125.5	153
154	136.8	67.7	70.1	68.3	62.1	103.7	100.8	92.0	126.4	154
155	137.7	68.2	70.6	68.8	62.6	104.4	101.5	92.6	127.2	155
156	138.6	68.6	71.1	69.2	63.1	105.1	102.2	93.2	128.0	156
157	139.5	69.1	71.6	69.7	63.6	105.8	102.8	93.8	128.9	157
158	140.3	69.5	72.0	70.2	64.1	106.5	103.5	94.4	129.7	158
159	141.2	70.0	72.5	70.7	64.5	107.2	104.2	95.0	130.5	159
160	142.1	70.4	73.0	71.2	65.0	107.9	104.8	95.6	131.4	160
161	143.0	70.9	73.4	71.6	65.5	108.5	105.5	96.2	132.2	161
162	143.9	71.4	73.9	72.1	66.0	109.2	106.2	96.8	133.0	162
163	144.8	71.8	74.4	72.6	66.5	109.9	106.9	97.4	133.9	163
164	145.7	72.3	74.9	73.1	66.9	110.6	107.5	98.0	134.7	164
165	146.6	72.8	75.3	73.6	67.4	111.3	108.2	98.6	135.5	165
166	147.5	73.2	75.8	74.0	67.9	112.0	108.9	99.2	136.4	166
167	148.3	73.7	76.3	74.5	68.4	112.7	109.6	99.8	137.2	167
168	149.2	74.1	76.8	75.0	68.9	113.4	110.2	100.4	138.0	168
169	150.1	74.6	77.2	75.5	69.3	114.1	110.9	101.0	138.9	169
170	151.0	75.1	77.7	76.0	69.8	114.8	111.6	101.6	139.7	170
171	151.9	75.5	78.2	76.4	70.3	115.4	112.3	102.2	140.5	171
172	152.8	76.0	78.7	76.9	70.8	116.1	112.9	102.8	141.4	172
173	153.7	76.4	79.1	77.4	71.3	116.8	113.6	103.5	142.2	173
174	154.6	76.9	79.6	77.9	71.7	117.5	114.3	104.1	143.0	174
175	155.5	77.4	80.1	78.4	72.2	118.2	114.9	104.7	143.9	175
176	156.3	77.8	80.6	78.8	72.7	118.9	115.6	105.3	144.7	176
177	157.2	78.3	81.0	79.3	73.2	119.6	116.3	105.9	145.5	177
178	158.1	78.8	81.5	79.8	73.7	120.3	117.0	106.5	146.4	178
179	159.0	79.2	82.0	80.3	74.2	121.0	117.6	107.1	147.2	179

TABLE 21—Continued

Cuprous oxid (Cu ₂ O)	Copper (Cu)	Dex- trose (d-glu- cose)	Invert sugar	Invert sugar and sucrose		Lactose C ₁₂ H ₂₂ O ₁₁ + H ₂ O	Lactose and sucrose		Maltose C ₁₂ H ₂₂ O ₁₁ + H ₂ O	Cu- prous oxid (CuO)
				0.4 gram total sugar	2 grams total sugar		1 lactose, 4 sucrose	1 lactose, 12 sucrose		
180	159.9	79.7	82.5	80.8	74.6	121.6	118.3	107.7	148.0	180
181	160.8	80.1	82.9	81.3	75.1	122.3	119.0	108.3	148.9	181
182	161.7	80.6	83.4	81.7	75.6	123.1	119.7	108.9	149.7	182
183	162.6	81.1	83.9	82.2	76.1	123.7	120.3	109.5	150.5	183
184	163.4	81.5	84.4	82.7	76.6	124.3	121.0	110.1	151.4	184
185	164.3	82.0	84.9	83.2	77.1	125.1	121.7	110.7	152.2	185
186	165.2	82.5	85.3	83.7	77.6	125.8	122.4	111.3	153.0	186
187	166.1	82.9	85.8	84.2	78.0	126.5	123.1	111.9	153.9	187
188	167.0	83.4	86.3	84.6	78.5	127.2	123.7	112.5	154.7	188
189	167.9	83.9	86.8	85.1	79.0	127.9	124.4	113.1	155.5	189
190	168.8	84.3	87.2	85.6	79.5	128.5	125.1	113.8	156.4	190
191	169.7	84.8	87.7	86.1	80.0	129.2	125.8	114.4	157.2	191
192	170.5	85.3	88.2	86.6	80.5	129.9	126.4	115.0	158.0	192
193	171.4	85.7	88.7	87.1	81.0	130.6	127.1	115.6	158.9	193
194	172.3	86.2	89.2	87.6	81.4	131.3	127.8	116.2	159.7	194
195	173.2	86.7	89.6	88.0	81.9	132.0	128.5	116.8	160.5	195
196	174.1	87.1	90.1	88.5	82.4	132.7	129.2	117.4	161.4	196
197	175.0	87.6	90.6	89.0	82.9	133.4	129.8	118.0	162.2	197
198	175.9	88.1	91.1	89.5	83.4	134.1	130.5	118.6	163.0	198
199	176.8	88.5	91.6	90.0	83.9	134.8	131.2	119.2	163.9	199
200	177.7	89.0	92.0	90.5	84.4	135.4	131.9	119.8	164.7	200
201	178.5	89.5	92.5	91.0	84.8	136.1	132.5	120.4	165.5	201
202	179.4	89.9	93.0	91.4	85.3	136.8	133.2	121.0	166.4	202
203	180.3	90.4	93.5	91.9	85.8	137.5	133.9	121.7	167.2	203
204	181.2	90.9	94.0	92.4	86.3	138.2	134.6	122.3	168.0	204
205	182.1	91.4	94.5	92.9	86.8	138.9	135.3	122.9	168.9	205
206	183.0	91.8	94.9	93.4	87.3	139.6	135.9	123.5	169.7	206
207	183.9	92.3	95.4	93.9	87.8	140.3	136.6	124.1	170.5	207
208	184.8	92.8	95.9	94.4	88.3	141.0	137.3	124.7	171.4	208
209	185.6	93.2	96.4	94.9	88.8	141.7	138.0	125.3	172.2	209
210	186.5	93.7	96.9	95.4	89.2	142.3	138.6	126.0	173.0	210
211	187.4	94.2	97.4	95.8	89.7	143.0	139.3	126.6	173.8	211
212	188.3	94.6	97.8	96.3	90.2	143.7	140.0	127.2	174.7	212
213	189.2	95.1	98.3	96.8	90.7	144.4	140.7	127.8	175.5	213
214	190.1	95.6	98.8	97.3	91.2	145.1	141.4	128.4	176.4	214
215	191.0	96.1	99.3	97.8	91.7	145.8	142.0	129.0	177.2	215
216	191.9	96.5	99.8	98.3	92.2	146.5	142.7	129.6	178.0	216
217	192.8	97.0	100.3	98.8	92.7	147.2	143.4	130.2	178.9	217
218	193.6	97.5	100.8	99.3	93.2	147.9	144.1	130.9	179.7	218
219	194.5	98.0	101.2	99.8	93.7	148.6	144.7	131.5	180.5	219
220	195.4	98.4	101.7	100.3	94.2	149.3	145.4	132.1	181.4	220
221	196.3	98.9	102.2	100.8	94.7	150.0	146.1	132.7	182.2	221
222	197.2	99.4	102.7	101.2	95.1	150.7	146.8	133.3	183.0	222
223	198.1	99.9	103.2	101.7	95.6	151.3	147.5	133.9	183.9	223
224	199.0	100.3	103.7	102.2	96.1	152.0	148.1	134.5	184.7	224
225	199.9	100.8	104.2	102.7	96.6	152.7	148.8	135.2	185.5	225
226	200.7	101.3	104.6	103.2	97.1	153.4	149.5	135.8	186.4	226
227	201.6	101.8	105.1	103.7	97.6	154.1	150.2	136.4	187.2	227
228	202.5	102.2	105.6	104.2	98.1	154.8	150.8	137.0	188.0	228
229	203.4	102.7	106.1	104.7	98.6	155.5	151.5	137.6	188.8	229
230	204.3	103.2	106.6	105.2	99.1	156.2	152.2	138.2	189.7	230
231	205.2	103.7	107.1	105.7	99.6	156.9	152.9	138.8	190.5	231
232	206.1	104.1	107.6	106.2	100.1	157.6	153.6	139.4	191.3	232
233	207.0	104.6	108.1	106.7	100.6	158.3	154.2	140.1	192.2	233
234	207.9	105.1	108.6	107.2	101.1	159.0	154.9	140.7	193.0	234
235	208.7	105.6	109.1	107.7	101.6	159.6	155.6	141.3	193.8	235
236	209.6	106.0	109.5	108.2	102.1	160.3	156.3	141.9	194.7	236
237	210.5	106.5	110.0	108.7	102.6	161.0	156.9	142.5	195.5	237
238	211.4	107.0	110.5	109.2	103.1	161.7	157.6	143.2	196.3	238
239	212.3	107.5	111.0	109.6	103.5	162.4	158.3	143.8	197.2	239

TABLE 21—Continued

Cuprous oxid (Cu ₂ O)	Copper (Cu)	Dex- trose (d-glu- cose)	Invert sugar	Invert sugar and sucrose		Lactose C ₁₂ H ₂₂ O ₁₁ + H ₂ O	Lactose and sucrose		Maltose C ₁₂ H ₂₂ O ₁₁ + H ₂ O	Cu- prous oxid (Cu ₂ O)
				0.4 gram total sugar	2 grams total sugar		1 lactose, 4 sucrose	1 lactose, 12 sucrose		
240	213.2	108.0	111.5	110.1	104.0	163.1	159.0	144.4	198.0	240
241	214.1	108.4	112.0	110.6	104.5	163.8	159.7	145.0	198.8	241
242	215.0	108.9	112.5	111.1	105.0	164.5	160.3	145.6	199.7	242
243	215.8	109.4	113.0	111.6	105.5	165.2	161.0	146.3	200.5	243
244	216.7	109.9	113.5	112.1	106.0	165.9	161.7	146.9	201.3	244
245	217.6	110.4	114.0	112.6	106.5	166.6	162.4	147.5	202.2	245
246	218.5	110.8	114.5	113.1	107.0	167.3	163.1	148.1	203.0	246
247	219.4	111.3	115.0	113.6	107.5	168.0	163.7	148.7	203.8	247
248	220.3	111.8	115.4	114.1	108.0	168.7	164.4	149.3	204.7	248
249	221.2	112.3	115.9	114.6	108.5	169.4	165.1	150.0	205.5	249
250	222.1	112.8	116.4	115.1	109.0	170.1	165.8	150.6	206.3	250
251	223.0	113.2	116.9	115.6	109.5	170.8	166.5	151.2	207.2	251
252	223.8	113.7	117.4	116.1	110.0	171.5	167.2	151.8	208.0	252
253	224.7	114.2	117.9	116.6	110.5	172.1	167.8	152.4	208.8	253
254	225.6	114.7	118.4	117.1	111.0	172.8	168.5	153.1	209.7	254
255	226.5	115.2	118.9	117.6	111.5	173.5	169.2	153.7	210.5	255
256	227.4	115.7	119.4	118.1	112.0	174.2	169.9	154.3	211.3	256
257	228.3	116.1	119.9	118.6	112.5	174.9	170.6	154.9	212.2	257
258	229.2	116.6	120.4	119.1	113.0	175.6	171.3	155.5	213.0	258
259	230.1	117.1	120.9	119.6	113.5	176.3	171.9	156.2	213.8	259
260	231.0	117.6	121.4	120.1	114.0	177.0	172.6	156.8	214.7	260
261	231.8	118.1	121.9	120.6	114.5	177.7	173.3	157.4	215.5	261
262	232.7	118.6	122.4	121.1	115.0	178.4	174.0	158.0	216.3	262
263	233.6	119.0	122.9	121.6	115.5	179.1	174.7	158.6	217.2	263
264	234.5	119.5	123.4	122.1	116.0	179.8	175.3	159.3	218.0	264
265	235.4	120.0	123.9	122.6	116.5	180.5	176.0	159.9	218.8	265
266	236.3	120.5	124.4	123.1	117.0	181.2	176.7	160.5	219.7	266
267	237.2	121.0	124.9	123.6	117.5	181.9	177.4	161.1	220.5	267
268	238.1	121.5	125.4	124.1	118.0	182.6	178.1	161.8	221.3	268
269	238.9	122.0	125.9	124.6	118.5	183.3	178.8	162.4	222.1	269
270	239.8	122.5	126.4	125.1	119.0	184.0	179.4	163.0	223.0	270
271	240.7	122.9	126.9	125.6	119.5	184.6	180.1	163.6	223.8	271
272	241.6	123.4	127.4	126.2	120.0	185.3	180.8	164.3	224.6	272
273	242.5	123.9	127.9	126.7	120.5	186.0	181.5	164.9	225.5	273
274	243.4	124.4	128.4	127.2	121.1	186.7	182.2	165.5	226.3	274
275	244.3	124.9	128.9	127.7	121.6	187.4	182.9	166.1	227.1	275
276	245.2	125.4	129.4	128.2	122.1	188.1	183.5	166.8	228.0	276
277	246.1	125.9	129.9	128.7	122.6	188.8	184.2	167.4	228.8	277
278	246.9	126.4	130.4	129.2	123.1	189.5	184.9	168.0	229.6	278
279	247.8	126.9	130.9	129.7	123.6	190.2	185.6	168.7	230.5	279
280	248.7	127.3	131.4	130.2	124.1	190.9	186.3	169.3	231.3	280
281	249.6	127.8	131.9	130.7	124.6	191.6	187.0	169.9	232.1	281
282	250.5	128.3	132.4	131.2	125.1	192.3	187.6	170.5	233.0	282
283	251.4	128.8	132.9	131.7	125.6	193.0	188.3	171.2	233.8	283
284	252.3	129.3	133.4	132.2	126.1	193.7	189.0	171.8	234.6	284
285	253.2	129.8	133.9	132.7	126.6	194.4	189.7	172.4	235.5	285
286	254.0	130.3	134.4	133.2	127.1	195.1	190.4	173.0	236.3	286
287	254.9	130.8	134.9	133.7	127.6	195.8	191.0	173.7	237.1	287
288	255.8	131.3	135.4	134.3	128.1	196.5	191.7	174.3	238.0	288
289	256.7	131.8	135.9	134.8	128.6	197.1	192.4	174.9	238.8	289
290	257.6	132.3	136.4	135.3	129.2	197.8	193.1	175.5	239.6	290
291	258.5	132.7	136.9	135.8	129.7	198.5	193.8	176.2	240.5	291
292	259.4	133.2	137.4	136.3	130.2	199.2	194.4	176.8	241.3	292
293	260.3	133.7	137.9	136.8	130.7	199.9	195.1	177.4	242.1	293
294	261.2	134.2	138.4	137.3	131.2	200.6	195.8	178.1	242.9	294
295	262.0	134.7	138.9	137.8	131.7	201.3	196.5	178.7	243.8	295
296	262.9	135.2	139.4	138.3	132.2	202.0	197.2	179.3	244.6	296
297	263.8	135.7	140.0	138.8	132.7	202.7	197.9	179.9	245.4	297
298	264.7	136.2	140.5	139.4	133.2	203.4	198.6	180.6	246.3	298
299	265.6	136.7	141.0	139.9	133.7	204.1	199.2	181.2	247.1	299

TABLE 21—Continued

Cuprous oxid (Cu ₂ O)	Copper (Cu)	Dex- trose (d-glu- cose)	Invert sugar	Invert sugar and sucrose		Lactose C ₁₂ H ₂₂ O ₁₁ + H ₂ O	Lactose and sucrose		Maltose C ₁₂ H ₂₂ O ₁₁ + H ₂ O	Cu- prous oxid (Cu ₂ O)
				0.4 gram total sugar	2 grams total sugar		1 lactose, 4 sucrose	1 lactose, 12 sucrose		
300	266.5	137.2	141.5	140.4	134.2	204.8	199.9	181.8	247.9	300
301	267.4	137.7	142.0	140.9	134.8	205.5	200.6	182.5	248.8	301
302	268.3	138.2	142.5	141.4	135.3	206.2	201.3	183.1	249.6	302
303	269.1	138.7	143.0	141.9	135.8	206.9	202.0	183.7	250.4	303
304	270.0	139.2	143.5	142.4	136.3	207.6	202.7	184.4	251.3	304
305	270.9	139.7	144.0	142.9	136.8	208.3	203.3	185.0	252.1	305
306	271.8	140.2	144.5	143.4	137.3	209.0	204.0	185.6	252.9	306
307	272.7	140.7	145.0	144.0	137.8	209.7	204.7	186.2	253.8	307
308	273.6	141.2	145.5	144.5	138.3	210.4	205.4	186.9	254.6	308
309	274.5	141.7	146.1	145.0	138.8	211.1	206.1	187.5	255.4	309
310	275.4	142.2	146.6	145.5	139.4	211.8	206.8	188.1	256.3	310
311	276.3	142.7	147.1	146.0	139.9	212.5	207.5	188.8	257.1	311
312	277.1	143.2	147.6	146.5	140.4	213.2	208.1	189.4	257.9	312
313	278.0	143.7	148.1	147.0	140.9	213.9	208.8	190.0	258.8	313
314	278.9	144.2	148.6	147.6	141.4	214.6	209.5	190.7	259.6	314
315	279.8	144.7	149.1	148.1	141.9	215.3	210.2	191.3	260.4	315
316	280.7	145.2	149.6	148.6	142.4	216.0	210.9	191.9	261.2	316
317	281.6	145.7	150.1	149.1	143.0	216.6	211.6	192.6	262.1	317
318	282.5	146.2	150.7	149.6	143.5	217.3	212.2	193.2	262.9	318
319	283.4	146.7	151.2	150.1	144.0	218.0	212.9	193.8	263.7	319
320	284.2	147.2	151.7	150.7	144.5	218.7	213.6	194.4	264.6	320
321	285.1	147.7	152.2	151.2	145.0	219.4	214.3	195.1	265.4	321
322	286.0	148.2	152.7	151.7	145.5	220.1	215.0	195.7	266.2	322
323	286.9	148.7	153.2	152.2	146.0	220.8	215.7	196.3	267.1	323
324	287.8	149.2	153.7	152.7	146.6	221.5	216.4	197.0	267.9	324
325	288.7	149.7	154.3	153.2	147.1	222.2	217.0	197.6	268.7	325
326	289.6	150.2	154.8	153.8	147.6	222.9	217.7	198.2	269.6	326
327	290.5	150.7	155.3	154.3	148.1	223.6	218.4	198.9	270.4	327
328	291.4	151.2	155.8	154.8	148.6	224.3	219.1	199.5	271.2	328
329	292.2	151.7	156.3	155.3	149.1	225.0	219.8	200.1	272.1	329
330	293.1	152.2	156.8	155.8	149.7	225.7	220.5	200.8	272.9	330
331	294.0	152.7	157.3	156.4	150.2	226.4	221.2	201.4	273.7	331
332	294.9	153.2	157.9	156.9	150.7	227.1	221.8	202.0	274.6	332
333	295.8	153.7	158.4	157.4	151.2	227.8	222.5	202.7	275.4	333
334	296.7	154.2	158.9	157.9	151.7	228.5	223.2	203.3	276.2	334
335	297.6	154.7	159.4	158.4	152.3	229.2	223.9	204.0	277.0	335
336	298.5	155.2	159.9	159.0	152.8	229.9	224.6	204.6	277.9	336
337	299.3	155.8	160.5	159.5	153.3	230.6	225.3	205.2	278.7	337
338	300.2	156.3	161.0	160.0	153.8	231.3	226.0	205.9	279.5	338
339	301.1	156.8	161.5	160.5	154.3	232.0	226.7	206.5	280.4	339
340	302.0	157.3	162.0	161.0	154.8	232.7	227.4	207.1	281.2	340
341	302.9	157.8	162.5	161.6	155.4	233.4	228.1	207.8	282.0	341
342	303.8	158.3	163.1	162.1	155.9	234.1	228.7	208.4	282.9	342
343	304.7	158.8	163.6	162.6	156.4	234.8	229.4	209.0	283.7	343
344	305.6	159.3	164.1	163.1	156.9	235.5	230.1	209.7	284.5	344
345	306.5	159.8	164.6	163.7	157.5	236.2	230.8	210.3	285.4	345
346	307.3	160.3	165.1	164.2	158.0	236.9	231.5	211.0	286.2	346
347	308.2	160.8	165.7	164.7	158.5	237.6	232.2	211.6	287.0	347
348	309.1	161.4	166.2	165.2	159.0	238.3	232.9	212.2	287.9	348
349	310.0	161.9	166.7	165.7	159.5	239.0	233.6	212.9	288.7	349
350	310.9	162.4	167.2	166.3	160.1	239.7	234.3	213.5	289.5	350
351	311.8	162.9	167.7	166.8	160.6	240.4	235.0	214.1	290.4	351
352	312.7	163.4	168.3	167.3	161.1	241.1	235.6	214.8	291.2	352
353	313.6	163.9	168.8	167.8	161.6	241.8	236.3	215.4	292.0	353
354	314.4	164.4	169.3	168.4	162.2	242.5	237.0	216.1	292.8	354
355	315.3	164.9	169.8	168.9	162.7	243.2	237.7	216.7	293.7	355
356	316.2	165.4	170.4	169.4	163.2	243.9	238.4	217.3	294.5	356
357	317.1	166.0	170.9	170.0	163.7	244.6	239.1	218.0	295.3	357
358	318.0	166.5	171.4	170.5	164.3	245.3	239.8	218.6	296.2	358
359	318.9	167.0	171.9	171.0	164.8	246.0	240.5	219.2	297.0	359
360	319.8	167.5	172.5	171.5	165.3	246.7	241.2	219.9	297.8	360
361	320.7	168.0	173.0	172.1	165.8	247.4	241.9	220.5	298.7	361
362	321.6	168.5	173.5	172.6	166.4	248.1	242.5	221.2	299.5	362
363	322.4	169.0	174.0	173.1	166.9	248.8	243.2	221.8	300.3	363
364	323.3	169.6	174.6	173.7	167.4	249.5	243.9	222.5	301.2	364

TABLE 21—Continued

Cuprous oxid (Cu ₂ O)	Copper (Cu)	Dex- trose (d-glu- cose)	Invert sugar	Invert sugar and sucrose		Lactose C ₁₂ H ₂₂ O ₁₁ + H ₂ O	Lactose and sucrose		Maltose C ₁₂ H ₂₂ O ₁₁ + H ₂ O	Cu- prous oxid (Cu ₂ O)
				0.4 gram total sugar	2 grams total sugar		1 lactose, 4 sucrose	1 lactose, 12 sucrose		
365	324.2	170.1	175.1	174.2	167.9	250.2	244.6	223.1	302.0	365
366	325.1	170.6	175.6	174.7	168.5	250.9	245.3	223.7	302.8	366
367	326.0	171.1	176.1	175.2	169.0	251.6	246.0	224.4	303.6	367
368	326.9	171.6	176.7	175.8	169.5	252.3	246.7	225.0	304.5	368
369	327.8	172.1	177.2	176.3	170.0	253.0	247.4	225.7	305.3	369
370	328.7	172.7	177.7	176.8	170.6	253.7	248.1	226.3	306.1	370
371	329.5	173.2	178.3	177.4	171.1	254.4	248.8	227.0	307.0	371
372	330.4	173.7	178.8	177.9	171.6	255.1	249.5	227.6	307.8	372
373	331.3	174.2	179.3	178.4	172.2	255.8	250.3	228.3	308.6	373
374	332.2	174.7	179.8	179.0	172.7	256.5	250.9	228.9	309.5	374
375	333.1	175.3	180.4	179.5	173.2	257.2	251.5	229.6	310.3	375
376	334.0	175.8	180.9	180.0	173.7	257.9	252.2	230.2	311.1	376
377	334.9	176.3	181.4	180.6	174.3	258.6	252.9	230.8	312.0	377
378	335.8	176.8	182.0	181.1	174.8	259.3	253.6	231.5	312.8	378
379	336.7	177.3	182.5	181.6	175.3	260.0	254.3	232.1	313.6	379
380	337.5	177.9	183.0	182.1	175.9	260.7	255.0	232.8	314.5	380
381	338.4	178.4	183.6	182.7	176.4	261.4	255.7	233.4	315.3	381
382	339.3	178.9	184.1	183.2	176.9	262.1	256.4	234.1	316.1	382
383	340.2	179.4	184.6	183.6	177.5	262.8	257.1	234.7	316.9	383
384	341.1	180.0	185.2	184.3	178.0	263.5	257.8	235.4	317.8	384
385	342.0	180.5	185.7	184.8	178.5	264.2	258.5	236.0	318.6	385
386	342.9	181.0	186.2	185.4	179.1	264.9	259.2	236.6	319.4	386
387	343.8	181.5	186.8	185.9	179.6	265.6	259.8	237.3	320.3	387
388	344.6	182.0	187.3	186.4	180.1	266.3	260.5	237.9	321.1	388
389	345.5	182.6	187.8	187.0	180.6	267.0	261.2	238.6	321.9	389
390	346.4	183.1	188.4	187.5	181.2	267.7	261.9	239.2	322.8	390
391	347.3	183.6	188.9	188.0	181.7	268.4	262.6	239.9	323.6	391
392	348.2	184.1	189.4	188.6	182.3	269.1	263.3	240.5	324.4	392
393	349.1	184.7	190.0	189.1	182.8	269.8	264.0	241.2	325.2	393
394	350.0	185.2	190.5	189.7	183.3	270.5	264.7	241.8	326.1	394
395	350.9	185.7	191.0	190.2	183.9	271.2	265.4	242.5	326.9	395
396	351.8	186.2	191.6	190.7	184.4	271.9	266.1	243.1	327.7	396
397	352.6	186.8	192.1	191.3	184.9	272.6	266.8	243.8	328.6	397
398	353.5	187.3	192.7	191.8	185.5	273.3	267.5	244.4	329.4	398
399	354.4	187.8	193.2	192.3	186.0	274.0	268.2	245.1	330.2	399
400	355.3	188.4	193.7	192.9	186.5	274.7	268.9	245.7	331.1	400
401	356.2	188.9	194.3	193.4	187.1	275.4	269.6	246.4	331.9	401
402	357.1	189.4	194.8	194.0	187.6	276.1	270.3	247.0	332.7	402
403	358.0	189.9	195.4	194.5	188.1	276.8	271.0	247.7	333.6	403
404	358.9	190.5	195.9	195.0	188.7	277.5	271.7	248.3	334.4	404
405	359.7	191.0	196.4	195.6	189.2	278.2	272.3	249.0	355.2	405
406	360.6	191.5	197.0	196.1	189.8	278.9	273.0	249.6	336.0	406
407	361.5	192.1	197.5	196.7	190.3	279.6	273.7	250.3	336.9	407
408	362.4	192.6	198.1	197.2	190.8	280.3	274.4	251.0	337.7	408
409	363.3	193.1	198.6	197.7	191.4	281.0	275.1	251.6	338.5	409
410	364.2	193.7	199.1	198.3	191.9	281.7	275.8	252.3	339.4	410
411	365.1	194.2	199.7	198.8	192.5	282.4	276.5	252.9	340.2	411
412	366.0	194.7	200.2	199.4	193.0	283.2	277.2	253.6	341.0	412
413	366.9	195.2	200.8	199.9	193.5	283.9	277.9	254.2	341.9	413
414	367.7	195.8	201.3	200.5	194.1	284.6	278.6	254.9	342.7	414
415	368.6	196.3	201.8	201.0	194.6	285.3	279.3	255.5	343.5	415
416	369.5	196.8	202.4	201.6	195.2	286.0	280.0	256.2	344.4	416
417	370.4	197.4	202.9	202.1	195.7	286.7	280.7	256.8	345.2	417
418	371.3	197.9	203.5	202.6	196.2	287.4	281.4	257.5	346.0	418
419	372.2	198.4	204.0	203.2	196.8	288.1	282.1	258.1	346.8	419
420	373.1	199.0	204.6	203.7	197.3	288.8	282.8	258.8	347.7	420
421	374.0	199.5	205.1	204.3	197.9	289.5	283.5	259.4	348.5	421
422	374.8	200.1	205.7	204.8	198.4	290.2	284.2	260.1	349.3	422
423	375.7	200.6	206.2	205.4	198.9	290.9	284.9	260.7	350.2	423
424	376.6	201.1	206.7	205.9	199.5	291.6	285.6	261.4	351.0	424
425	377.5	201.7	207.3	206.5	200.0	292.3	286.3	262.1	351.8	425
426	378.4	202.2	207.8	207.0	200.6	293.0	287.0	262.7	352.7	426
427	379.3	202.8	208.4	207.6	201.1	293.7	287.7	263.4	353.5	427
428	380.2	203.3	208.9	208.1	201.7	294.4	288.4	264.0	354.3	428
429	381.1	203.8	209.5	208.7	202.2	295.1	289.1	264.7	355.1	429

TABLE 21—Continued

Cuprous oxid (Cu ₂ O)	Copper (Cu)	Dex- trose (d-glu- cose)	Invert sugar	Invert sugar and sucrose		Lactose C ₁₂ H ₂₂ O ₁₁ + H ₂ O	Lactose and sucrose		Maltose C ₁₂ H ₂₂ O ₁₁ + H ₂ O	Cu- prous oxid (Cu ₂ O)
				0.4 gram total sugar	2 grams total sugar		1 lactose, 4 sucrose	1 lactose, 12 sucrose		
430	382.0	204.4	210.0	209.2	202.7	295.8	289.8	265.4	356.0	430
431	382.8	204.9	210.6	209.8	203.3	296.5	290.5	266.0	356.8	431
432	383.7	205.5	211.1	210.3	203.8	297.2	291.2	266.7	357.6	432
433	384.6	206.0	211.7	210.9	204.4	297.9	291.9	267.3	358.5	433
434	385.5	206.5	212.2	211.4	204.9	298.6	292.6	268.0	359.3	434
435	386.4	207.1	212.8	212.0	205.5	299.3	293.3	268.7	360.1	435
436	387.3	207.6	213.3	212.5	206.0	300.0	294.0	269.3	361.0	436
437	388.2	208.2	213.9	213.1	206.6	300.7	294.7	270.0	361.8	437
438	389.1	208.7	214.4	213.6	207.1	301.4	295.4	270.6	362.6	438
439	390.0	209.2	215.0	214.2	207.7	302.1	296.1	271.3	363.4	439
440	390.8	209.8	215.5	214.7	208.2	302.8	296.8	272.0	364.3	440
441	391.7	210.3	216.1	215.3	208.8	303.5	297.5	272.6	365.1	441
442	392.6	210.9	216.6	215.8	209.3	304.2	298.2	273.3	365.9	442
443	393.5	211.4	217.2	216.4	209.9	304.9	298.9	273.9	366.8	443
444	394.4	212.0	217.8	216.9	210.4	305.6	299.6	274.6	367.6	444
445	395.3	212.5	218.3	217.5	211.0	306.3	300.3	275.3	368.4	445
446	396.2	213.1	218.9	218.0	211.5	307.0	301.0	275.9	369.3	446
447	397.1	213.6	219.4	218.6	212.1	307.7	301.7	276.6	370.1	447
448	397.9	214.1	220.0	219.1	212.6	308.4	302.4	277.2	370.9	448
449	398.8	214.7	220.5	219.7	213.2	309.1	303.1	277.9	371.7	449
450	399.7	215.2	221.1	220.2	213.7	309.9	303.8	278.6	372.6	450
451	400.6	215.8	221.6	220.8	214.3	310.6	304.5	279.2	373.4	451
452	401.5	216.3	222.2	221.4	214.8	311.3	305.2	279.9	374.2	452
453	402.4	216.9	222.8	221.9	215.4	312.0	305.9	280.5	375.1	453
454	403.3	217.4	223.3	222.5	215.9	312.7	306.6	281.2	375.9	454
455	404.2	218.0	223.9	223.0	216.5	313.4	307.3	281.9	376.7	455
456	405.1	218.5	224.4	223.6	217.0	314.1	308.0	282.5	377.6	456
457	405.9	219.1	225.0	224.1	217.6	314.8	308.7	283.2	378.4	457
458	406.8	219.6	225.5	224.7	218.1	315.5	309.4	283.9	379.2	458
459	407.7	220.2	226.1	225.3	218.7	316.2	310.1	284.5	380.0	459
460	408.6	220.7	226.7	225.8	219.2	316.9	310.8	285.2	380.9	460
461	409.5	221.3	227.3	226.4	219.8	317.6	311.5	285.9	381.7	461
462	410.4	221.8	227.8	226.9	220.3	318.3	312.2	286.5	382.5	462
463	411.3	222.4	228.3	227.5	220.9	319.0	312.9	287.2	383.4	463
464	412.2	222.9	228.9	228.1	221.4	319.7	313.6	287.8	384.2	464
465	413.0	223.5	229.5	228.6	222.0	320.4	314.3	288.5	385.0	465
466	413.9	224.0	230.0	229.2	222.5	321.1	315.0	289.2	385.9	466
467	414.8	224.6	230.6	229.7	223.1	321.8	315.7	289.8	386.7	467
468	415.7	225.1	231.2	230.3	223.7	322.5	316.4	290.5	387.5	468
469	416.6	225.7	231.7	230.9	224.2	323.2	317.0	291.2	388.3	469
470	417.5	226.2	232.3	231.4	224.8	323.9	317.7	291.8	389.2	470
471	418.4	226.8	232.8	232.0	225.3	324.6	318.4	292.5	390.0	471
472	419.3	227.4	233.4	232.5	225.9	325.3	319.1	293.2	390.8	472
473	420.2	227.9	234.0	233.1	226.4	326.0	319.8	293.8	391.7	473
474	421.0	228.3	234.5	233.7	227.0	326.8	320.5	294.5	392.5	474
475	421.9	229.0	235.1	234.2	227.6	327.5	321.2	295.2	393.3	475
476	422.8	229.6	235.7	234.8	228.1	328.2	321.9	295.8	394.2	476
477	423.7	230.1	236.2	235.4	228.7	328.9	322.6	296.5	395.0	477
478	424.6	230.7	236.8	235.9	229.2	329.6	323.3	297.1	395.8	478
479	425.5	231.3	237.4	236.5	229.8	330.3	324.0	297.8	396.6	479
480	426.4	231.8	237.9	237.1	230.3	331.0	324.7	298.5	397.5	480
481	427.3	232.4	238.5	237.6	230.9	331.7	325.4	299.1	398.3	481
482	428.1	232.9	239.1	238.2	231.5	332.4	326.1	299.8	399.1	482
483	429.0	233.5	239.6	238.8	232.0	333.1	326.8	300.5	400.0	483
484	429.9	234.1	240.2	239.3	232.6	333.8	327.5	301.1	400.8	484
485	430.8	234.6	240.8	239.9	233.2	334.5	328.2	301.8	401.6	485
486	431.7	235.2	241.4	240.5	233.7	335.2	328.9	302.5	402.4	486
487	432.6	235.7	241.9	241.0	234.3	335.9	329.6	303.1	403.3	487
488	433.5	236.3	242.5	241.6	234.8	336.6	330.3	303.8	404.1	488
489	434.4	236.9	243.1	242.2	235.4	337.3	331.0	304.5	404.9	489
490	435.3	237.4	243.6	242.7	236.0	338.0	331.7	305.1	405.8	490

TABLE 22

Herzfeld's Table for Determining Invert Sugar in Raw Sugars (Invert Sugar not to Exceed 1.5 Per Cent)

Copper (Cu)	Invert sugar	Copper (Cu)	Invert sugar	Copper (Cu)	Invert sugar	Copper (Cu)	Invert sugar	Copper (Cu)	Invert sugar
Mgs	Per cent	Mgs	Per cent	Mgs	Per cent	Mgs	Per cent	Mgs	Per cent
50	0.050	105	0.325	160	0.621	215	0.929	270	1.242
51	0.054	106	0.330	161	0.627	216	0.935	271	1.248
52	0.058	107	0.335	162	0.633	217	0.940	272	1.253
53	0.062	108	0.340	163	0.639	218	0.946	273	1.259
54	0.066	109	0.346	164	0.645	219	0.951	274	1.265
55	0.070	110	0.351	165	0.651	220	0.957	275	1.271
56	0.074	111	0.356	166	0.657	221	0.962	276	1.276
57	0.078	112	0.361	167	0.663	222	0.968	277	1.282
58	0.082	113	0.366	168	0.669	223	0.973	278	1.288
59	0.086	114	0.371	169	0.675	224	0.979	279	1.294
60	0.090	115	0.376	170	0.680	225	0.984	280	1.299
61	0.094	116	0.381	171	0.686	226	0.990	281	1.305
62	0.098	117	0.386	172	0.692	227	0.996	282	1.311
63	0.103	118	0.392	173	0.698	228	1.001	283	1.317
64	0.108	119	0.397	174	0.704	229	1.007	284	1.322
65	0.113	120	0.402	175	0.709	230	1.013	285	1.328
66	0.118	121	0.407	176	0.715	231	1.018	286	1.334
67	0.123	122	0.412	177	0.720	232	1.024	287	1.339
68	0.128	123	0.417	178	0.726	233	1.030	288	1.345
69	0.133	124	0.423	179	0.731	234	1.036	289	1.351
70	0.138	125	0.428	180	0.737	235	1.041	290	1.357
71	0.143	126	0.433	181	0.742	236	1.047	291	1.362
72	0.148	127	0.438	182	0.748	237	1.053	292	1.368
73	0.152	128	0.443	183	0.753	238	1.058	293	1.374
74	0.157	129	0.448	184	0.759	239	1.064	294	1.380
75	0.162	130	0.453	185	0.764	240	1.070	295	1.385
76	0.167	131	0.458	186	0.770	241	1.076	296	1.391
77	0.172	132	0.463	187	0.775	242	1.081	297	1.397
78	0.177	133	0.468	188	0.781	243	1.087	298	1.403
79	0.182	134	0.473	189	0.786	244	1.093	299	1.408
80	0.187	135	0.478	190	0.792	245	1.099	300	1.414
81	0.192	136	0.483	191	0.797	246	1.104	301	1.420
82	0.197	137	0.488	192	0.803	247	1.110	302	1.425
83	0.202	138	0.493	193	0.808	248	1.116	303	1.431
84	0.208	139	0.498	194	0.814	249	1.122	304	1.437
85	0.213	140	0.503	195	0.819	250	1.127	305	1.443
86	0.219	141	0.509	196	0.825	251	1.133	306	1.448
87	0.225	142	0.515	197	0.830	252	1.139	307	1.454
88	0.231	143	0.521	198	0.836	253	1.144	308	1.460
89	0.236	144	0.527	199	0.841	254	1.150	309	1.466
90	0.242	145	0.533	200	0.847	255	1.156	310	1.471
91	0.248	146	0.538	201	0.852	256	1.162	311	1.477
92	0.254	147	0.544	202	0.858	257	1.167	312	1.483
93	0.260	148	0.550	203	0.863	258	1.173	313	1.489
94	0.265	149	0.556	204	0.869	259	1.179	314	1.494
95	0.271	150	0.562	205	0.874	260	1.185	315	1.500
96	0.277	151	0.568	206	0.880	261	1.190		
97	0.283	152	0.574	207	0.885	262	1.196		
98	0.288	153	0.580	208	0.891	263	1.202		
99	0.294	154	0.586	209	0.896	264	1.207		
100	0.300	155	0.592	210	0.902	265	1.213		
101	0.305	156	0.598	211	0.907	266	1.219		
102	0.310	157	0.604	212	0.913	267	1.225		
103	0.315	158	0.609	213	0.918	268	1.231		
104	0.320	159	0.615	214	0.924	269	1.236		

TABLE 23

Allihn's table for the determination of dextrose

Milligrams of copper	Milli-grams of cuprous oxid	Milli-grams of dextrose	Milli-grams of copper	Milli-grams of cuprous oxid	Milli-grams of dextrose	Milli-grams of copper	Milli-grams of cuprous oxid	Milli-grams of dextrose	Milli-grams of copper	Milli-grams of cuprous oxid	Milli-grams of dextrose
11	12.4	6.6	71	79.9	36.3	131	147.5	66.7	191	215.0	97.8
12	13.5	7.1	72	81.1	36.8	132	148.6	67.2	192	216.2	98.4
13	14.6	7.6	73	82.2	37.3	133	149.7	67.7	193	217.3	98.9
14	15.8	8.1	74	83.3	37.8	134	150.9	68.2	194	218.4	99.4
15	16.9	8.6	75	84.4	38.3	135	152.0	68.8	195	219.5	100.0
16	18.0	9.0	76	85.6	38.8	136	153.1	69.3	196	220.7	100.5
17	19.1	9.5	77	86.7	39.3	137	154.2	69.8	197	221.8	101.0
18	20.3	10.0	78	87.8	39.8	138	155.4	70.3	198	222.9	101.5
19	21.4	10.5	79	88.9	40.3	139	156.5	70.8	199	224.0	102.0
20	22.5	11.0	80	90.1	40.8	140	157.6	71.3	200	225.2	102.6
21	23.6	11.5	81	91.2	41.3	141	158.7	71.8	201	226.3	103.1
22	24.8	12.0	82	92.3	41.8	142	159.9	72.3	202	227.4	103.7
23	25.9	12.5	83	93.4	42.3	143	161.0	72.9	203	228.5	104.2
24	27.0	13.0	84	94.6	42.8	144	162.1	73.4	204	229.7	104.7
25	28.1	13.5	85	95.7	43.4	145	163.2	73.9	205	230.8	105.3
26	29.3	14.0	86	96.8	43.9	146	164.4	74.4	206	231.9	105.8
27	30.4	14.5	87	97.9	44.4	147	165.5	74.9	207	233.0	106.3
28	31.5	15.0	88	99.1	44.9	148	166.6	75.5	208	234.2	106.8
29	32.7	15.5	89	100.2	45.4	149	167.7	76.0	209	235.3	107.4
30	33.8	16.0	90	101.3	45.9	150	168.9	76.5	210	236.4	107.9
31	34.9	16.5	91	102.4	46.4	151	170.0	77.0	211	237.6	108.4
32	36.0	17.0	92	103.6	46.9	152	171.1	77.5	212	238.7	109.0
33	37.2	17.5	93	104.7	47.4	153	172.3	78.1	213	239.8	109.5
34	38.3	18.0	94	105.8	47.9	154	173.4	78.6	214	240.9	110.0
35	39.4	18.5	95	107.0	48.4	155	174.5	79.1	215	242.1	110.6
36	40.5	18.9	96	108.1	48.9	156	175.6	79.6	216	243.2	111.1
37	41.7	19.4	97	109.2	49.4	157	176.8	80.1	217	244.3	111.6
38	42.8	19.9	98	110.3	49.9	158	177.9	80.7	218	245.4	112.1
39	43.9	20.4	99	111.5	50.4	159	179.0	81.2	219	246.6	112.7
40	45.0	20.9	100	112.6	50.9	160	180.1	81.7	220	247.7	113.2
41	46.2	21.4	101	113.7	51.4	161	181.3	82.2	221	248.7	113.7
42	47.3	21.9	102	114.8	51.9	162	182.4	82.7	222	249.9	114.3
43	48.4	22.4	103	116.0	52.4	163	183.5	83.3	223	251.0	114.8
44	49.5	22.9	104	117.1	52.9	164	184.6	83.8	224	252.4	115.3
45	50.7	23.4	105	118.2	53.5	165	185.8	84.3	225	253.3	115.9
46	51.8	23.9	106	119.3	54.0	166	186.9	84.8	226	254.4	116.4
47	52.9	24.4	107	120.5	54.5	167	188.0	85.3	227	255.6	116.9
48	54.0	24.9	108	121.6	55.0	168	189.1	85.9	228	256.7	117.4
49	55.2	25.4	109	122.7	55.5	169	190.3	86.4	229	257.8	118.0
50	56.3	25.9	110	123.8	56.0	170	191.4	86.9	230	258.9	118.5
51	57.4	26.4	111	125.0	56.5	171	192.5	87.4	231	260.1	119.0
52	58.5	26.9	112	126.1	57.0	172	193.6	87.9	232	261.2	119.6
53	59.7	27.4	113	127.2	57.5	173	194.8	88.5	233	262.3	120.1
54	60.8	27.9	114	128.3	58.0	174	195.9	89.0	234	263.4	120.7
55	61.9	28.4	115	129.6	58.6	175	197.0	89.5	235	264.6	121.2
56	63.0	28.8	116	130.6	59.1	176	198.1	90.0	236	265.7	121.7
57	64.2	29.3	117	131.7	59.6	177	199.3	90.5	237	266.8	122.3
58	65.3	29.8	118	132.8	60.1	178	200.4	91.1	238	268.0	122.8
59	66.4	30.3	119	134.0	60.6	179	201.5	91.6	239	269.1	123.4
60	67.6	30.8	120	135.1	61.1	180	202.6	92.1	240	270.2	123.9
61	68.7	31.3	121	136.2	61.6	181	203.8	92.6	241	271.3	124.4
62	69.8	31.8	122	137.4	62.1	182	204.9	93.1	242	272.5	125.0
63	70.9	32.3	123	138.5	62.6	183	206.0	93.7	243	273.6	125.5
64	72.1	32.8	124	139.6	63.1	184	207.1	94.2	244	274.7	126.0
65	73.2	33.3	125	140.7	63.7	185	208.3	94.7	245	275.8	126.6
66	74.3	33.8	126	141.9	64.2	186	209.4	95.2	246	277.0	127.1
67	75.4	34.3	127	143.0	64.7	187	210.5	95.7	247	278.1	127.6
68	76.6	34.8	128	144.1	65.2	188	211.7	96.3	248	279.2	128.1
69	77.7	35.3	129	145.2	65.7	189	212.8	96.8	249	280.3	128.7
70	78.8	35.8	130	146.4	66.2	190	213.9	97.3	250	281.5	129.2

TABLE 23—Continued

Milligrams of copper	Milli-grams of cuprous oxid	Milli-grams of dextrose	Milli-grams of copper	Milli-grams of cuprous oxid	Milli-grams of dextrose	Milli-grams of copper	Milli-grams of cuprous oxid	Milli-grams of dextrose	Milli-grams of copper	Milli-grams of cuprous oxid	Milli-grams of dextrose
251	282.6	129.7	305	343.4	159.3	359	404.2	189.4	413	465.0	220.4
252	283.7	130.3	306	344.5	159.8	360	405.3	190.0	414	466.1	221.0
253	284.8	130.8	307	345.6	160.4	361	406.4	190.6	415	467.2	221.6
254	286.0	131.4	308	346.8	160.9	362	407.6	191.1	416	468.4	222.2
255	287.1	131.9	309	347.9	161.5	363	408.7	191.7	417	469.5	222.8
256	288.2	132.4	310	349.0	162.0	364	409.8	192.3	418	470.6	223.3
257	289.3	133.0	311	350.1	162.6	365	410.9	192.9	419	471.8	223.9
258	290.5	133.5	212	351.3	163.1	366	412.1	193.4	420	472.9	224.5
259	291.6	134.1	313	352.4	163.7	367	413.2	194.0	421	474.0	225.1
260	292.7	134.6	314	353.5	164.2	368	414.3	194.6	422	475.6	225.7
261	293.8	135.1	315	354.6	164.8	369	415.4	195.1	423	476.2	226.3
262	295.0	135.7	316	355.8	165.3	370	416.6	195.7	424	477.4	226.9
263	296.1	136.2	317	356.9	165.9	371	417.7	196.3	425	478.5	227.5
264	297.2	136.8	318	358.0	166.4	372	418.8	196.8	426	479.6	228.0
265	298.3	137.3	319	359.1	167.0	373	420.0	197.4	427	480.7	228.6
266	299.5	137.8	320	360.3	167.5	374	421.1	198.0	428	481.9	229.2
267	300.6	138.4	321	361.4	168.1	375	422.2	198.6	429	483.0	229.8
268	301.7	138.9	322	362.5	168.6	376	423.3	199.1	430	484.1	230.4
269	302.8	139.5	323	363.7	169.2	377	424.5	199.7	431	485.3	231.0
270	304.0	140.0	324	364.8	169.7	378	425.6	200.3	432	486.4	231.6
271	305.1	140.6	325	365.9	170.3	379	426.7	200.8	433	487.5	232.2
272	306.2	141.1	326	367.0	170.9	380	427.8	201.4	434	488.6	232.8
273	307.3	141.7	327	368.2	171.4	381	429.0	202.0	435	489.7	233.4
274	308.5	142.2	328	369.3	172.0	382	430.1	202.5	436	490.9	233.9
275	309.6	142.8	329	370.4	172.5	383	431.2	203.1	437	492.0	234.5
276	310.7	143.3	330	371.5	173.1	384	432.3	203.7	438	493.1	235.1
277	311.9	143.9	331	372.7	173.7	385	433.5	204.3	439	494.3	235.7
278	313.0	144.4	332	373.8	174.2	386	434.6	204.8	440	495.4	236.3
279	314.1	145.0	333	374.9	174.8	387	435.7	205.4	441	496.5	236.9
280	315.2	145.5	334	376.0	175.3	388	436.8	206.0	442	497.6	237.5
281	316.4	146.1	335	377.2	175.9	389	438.0	206.5	443	498.8	238.1
282	317.5	146.6	336	378.3	176.5	390	439.1	207.1	444	499.9	238.7
283	318.6	147.2	337	379.4	177.0	391	440.2	207.7	445	501.0	239.3
284	319.7	147.7	338	380.5	177.6	392	441.3	208.3	446	502.1	239.8
285	320.9	148.3	339	381.7	178.1	393	442.4	208.8	447	503.2	240.4
286	322.0	148.8	340	382.8	178.7	394	443.6	209.4	448	504.4	241.0
287	323.1	149.4	341	383.9	179.3	395	444.7	210.0	449	505.5	241.6
288	324.2	149.9	342	385.0	179.8	396	445.9	210.6	450	506.6	242.2
289	325.4	150.5	343	386.2	180.4	397	447.0	211.2	451	507.8	242.8
290	326.5	151.0	344	387.3	180.9	398	448.1	211.7	452	508.9	243.4
291	327.4	151.6	345	388.4	181.5	399	449.2	212.3	453	510.0	244.0
292	328.7	152.1	346	389.6	182.1	400	450.3	212.9	454	511.1	244.6
293	329.9	152.7	347	390.7	182.6	401	451.5	213.5	455	512.3	245.2
294	331.0	153.2	348	391.8	183.2	402	452.6	214.1	456	513.4	245.7
295	332.1	153.8	349	392.9	183.7	403	453.7	214.6	457	514.5	246.3
296	333.3	154.3	350	394.0	184.3	404	454.8	215.2	458	515.6	246.9
297	334.4	154.9	351	395.2	184.9	405	456.0	215.8	459	516.8	247.5
298	335.5	155.4	352	396.3	185.4	406	457.1	216.4	460	517.9	248.1
299	336.6	156.0	353	397.4	186.0	407	458.2	217.0	461	519.0	248.7
300	337.8	156.5	354	398.6	186.6	408	459.4	217.5	462	520.1	249.3
301	338.9	157.1	355	399.7	187.2	409	460.5	218.1	463	521.3	249.9
302	340.0	157.6	356	400.8	187.7	410	461.6	218.7			
303	341.1	158.2	357	401.9	188.3	411	462.7	219.3			
304	342.3	158.7	358	403.1	188.9	412	463.8	219.9			

TABLE 25

Interpolation Formulas for Specific Rotation

Sucrose	$[\alpha]_{\text{D}}^{20} = 66.412 + 0.012673p - 0.0003766p^2$
Dextrose	$[\alpha]_{\text{D}}^{20} = 52.50 + 0.0188p + 0.000517p^2$
Fructose	$[\alpha]_{\text{D}}^{20} = -113.96 + 0.258q$ ($q = \% \text{ water}$)
Maltose	$[\alpha]_{\text{D}}^{20} = 138.475 - 0.01837p$
Lactose	$[\alpha]_{\text{D}}^{20} = 52.53$
Invert sugar	$[\alpha]_{\text{D}}^{20} = -19.447 - 0.06068p + 0.000221p^2$

TABLE 26

Interpolation Table of Specific Rotations at Varying Concentrations

Percentage	Sucrose	Dextrose	Fructose	Maltose	Lactose hydrate
5.....	66.466	52.607	-89.42	138.38	52.53 Remains unchanged at all concentrations
10.....	66.501	52.740	-90.72	138.29	
15.....	66.517	52.898	-92.01	138.20	
20.....	66.515	53.083	-93.30	138.11	
25.....	66.493	53.293	-94.59	138.02	
30.....	66.453	53.529	-95.88	137.92	
35.....	66.394	53.791	-97.18	137.82	
40.....	66.316	54.079	-98.47	.....	
45.....	66.220	54.393	.....	.....	
50.....	66.104	54.732	.....	.....	

TABLE 27⁷¹

Correction to saccharimetric dextrose reading for variation of specific rotation

Scale division.....	100	90	80	70	60	50	40	30	20	10	1
Correction to be added.....	.00	.20	.35	.45	.50	.51	.48	.41	.30	.17	.02

⁷¹ Browne: J. Ind. Eng. Chem., 2, p. 526.

TABLE 28

Time Required at Each Temperature to Form Caramel Equivalent to .01 Per Cent of Invert Sugar.

Temperature.....	79.5	66.6	50.0	39.0
Time in hours.....	.57	10.9	107.	476.

